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PRELIMINARY INVESTIGATION OF GENERAL-PURPOSE MAT/PANEL MATERIAL--ETC(U)
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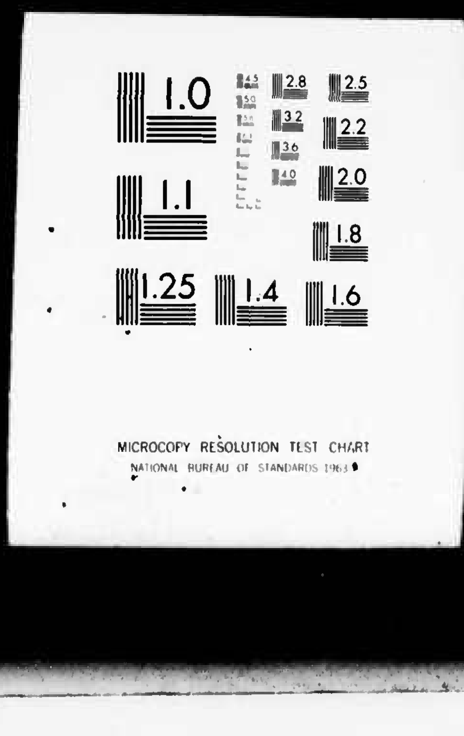
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PRELIMINARY INVESTIGATION OF GENERAL-PURPOSE MAT/PANEL MATERIALS

by

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Final Report

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this study was to determine the feasibility of providing a general-purpose mat/panel for the theater of operations for multiusages other than as aircraft landing mats and to establish criteria for future design of such mat/panels. Several test sections were used to test 11 different fabricated designs of materials and several additional materials were tested as potential items. The test materials were placed on a loose dry sand which had an initial average CBR of 1.5 at the surface and 2.6 at a 6-in. depth. The overall sand section was 75 by 16 by 1 ft deep. Accelerated traffic was applied (Continued)

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20. ABSTRACT (Cont'd):

using an M54, 5-ton military truck loaded with 20,000 lb for a gross load of 40,000 lb and with tires inflated to 70 psi. Comparative laboratory tests of the structural properties of the panels were also conducted.

Eight of the 11 panels tested (Wells, Woodside, Kaiser 2.5 and 3.0 lb, Alcoa, Taber, Fletcher, and M8A1) sustained the total traffic of 3000 passes. Of these eight mat/panels that sustained the 3000 traffic passes, five (Woodside, Kaiser 2.5 and 3.0 lb, Taber, and Fletcher) satisfied the desired 3.0-lb-per-sq-ft maximum weight. The Wells (3.2 lb per sq ft) panels were only 6 percent and the Alcoa (3.5 lb per sq ft) 17 percent heavier than the desired weight. The M8A1 (7.5 lb per sq ft) was 2.5 times heavier than the desired weight.

Four of the panels (Wells, Taber, Alcoa, Gill) sustained the maximum crush test of 1250 psi. The Kaiser 2.5-lb panel sustained 87 percent and the Woodside sustained 64 percent of this load.

From these tests, the following criteria were established as a guideline in further testing and developing a general-purpose mat/panel:

a. The panels must be capable of sustaining 3000 passes of the M54 truck with gross weight of 40,000 lb using tires inflated to 70 psi on a loose dry sandy soil.

b. Individual mats must be of such size, shape, and weight as to be handled by two men (desirable maximum weight, 100 lb; essential maximum weight, 120 lb; maximum dimensions, 12 by 4 ft. The 12-ft length and 3.0-lb-per-sq-ft weight are maximums.). Half-panels may be required.

c. Panels must be provided with connectors on all edges. Ancillaries must be provided to make 90-deg corner connectors for vertical construction.

d. Panels must be coated with an antiskid to provide a coefficient of friction between 0.4 and 0.8 when wet or dry.

e. Panels must withstand a crushing load of 1250 psi, as determined when using a container corner.

f. Mats must support 400 lb per ft of width at a maximum deflection of 4 in. when tested as a beam using a 10-ft span and 1/3-point loading.

g. Mats must support 4000 lb per ft of width at a maximum midpoint deflection of 4 in. when tested as a 12-ft column.

h. Multimillion square feet production cost should be approximately $3.00 per sq ft.

Further studies and tests are recommended for the Kaiser 2.5-lb honeycomb, Wells extruded aluminum, and Woodside formed aluminum panels for use as a general-purpose panel. Additional studies and tests are needed to determine the optimum cell size and core thickness for the Ecolite and Hexcel core materials for over-the-beach usage and/or for soil strengthening for vehicular traffic.

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PREFACE

This study was conducted under DA Project 1T162112A528, Task 04, and Project 1F763726DG01, Task 11, titled "Expedient Surfacing and Soil Stabilization" and "General Purpose Mat/Panel," respectively, sponsored by the U. S. Army Materiel Development and Readiness Command.

The tests pertinent to this investigation were performed at the U. S. Army Engineer Waterways Experiment Station (WES) during May-September 1976 under the general supervision of Messrs. James P. Sale, Chief; Richard G. Ahlvin, Assistant Chief; and Ronald L. Hutchinson, Pavement Program Manager, of the Soils and Pavements Laboratory (S&PL). Personnel of the Materiel Development Division, S&PL, actively engaged in the planning, testing, analyzing, and reporting phases of the investigation were Messrs. William L. McInnis, Hugh L. Green, Dewey W. White, Jr., Gordon L. Carr, Carroll J. Smith, and Dave A. Ellison. The Engineering and Construction Services Division had the Responsibility of constructing and trafficking the test sections under the supervision of Messrs. J. M. Peterson and Edward Stephens. This report was prepared by Messrs. Green, White, and Carr.

Directors of WES during the conduct of this study and preparation of this report were COL G. H. Hilt, CE, and COL John L. Cannon, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
inches	25.4	millimetres
feet	0.3048	metres
square feet	0.09290304	square metres
pounds (mass)	0.4535924	kilograms
tons (2000 lb, mass)	907.1847	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (force)	4.448222	newtons
pounds (force) per square inch	6894.757	pascals
degrees (angular)	0.01745329	radians

PRELIMINARY INVESTIGATION OF GENERAL-PURPOSE MAT/PANEL MATERIALS

PART I: INTRODUCTION

Purpose

1. The purpose of this study was to establish the requirements for and determine the feasibility of providing a general-purpose item for use in rapid assembly on roadways, parking and maintenance areas, depot storage areas, and POL sites. The ultimate mat/panel design will also be used for such purposes as personnel support floors; flooring for tent erection areas, gun emplacements, and hospitals; revetments for protection of personnel and equipment; and for expedient construction of bunkers, headwalls, and culverts. The study included examinations of materials fabricated using three different methods of fabrication: formed metal, bonded sandwich structure, and extruded aluminum. The research work conducted under this study is related to work previously conducted under landing mat programs; however, the general-purpose mat/panel will not be subject to requirements involving aircraft operations. The specific purpose was to actually procure various potential sample designs of materials for preliminary examination in traffic and laboratory testing in comparison-type evaluations.

Scope

2. Eleven different designs of materials were procured in small experimental quantities for evaluation in this study and some additional materials were provided for tests in related studies. Some of the designs were of U. S. Army Engineer Waterways Experiment Station (WES) origin, and others were designed by the fabricator or were "off-the-shelf" type items that were essentially commercially available from a fabricator as offsprings from other applications. These materials were examined physically for comparisons with respect to weight, cost,

load-carrying ability for static loads (both as beams and as columns), load-carrying ability for a rolling wheel load on a low-strength subgrade, and the feasibility of the materials satisfying other structural requirements of a general-purpose mat/panel. Based on these investigations with a minimum expenditure of procurement funds, a position as to the feasibility of designing and developing this type of item was established.

Background

3. Since the various airfield landing mats first became available during World War II, extensive uses have been found in valid applications other than that for which they were designed and optimized. During World War II, over 800 million sq ft* of mat was used; the Korean conflict required over 65 million sq ft; and over 165 million sq ft of mat was used in Viet Nam. However, in each case, only about 10 percent or less was used for airfields as intended. Thus, there is an obvious need for a general-purpose material that is specifically designed to better meet the many purposes to which such a structural element would be applied. Therefore, it was hoped that this study would result in a material that would be significantly more cost effective, remain an inventory item not subject to possible degradation with improvement to airfield surfacing, and be available in preference to diversions of more critical heavy-duty airfield matting. This airfield matting ranges in weight from 4.2 lb per sq ft up to 7.5 lb per sq ft depending on the category. Therefore, a general-purpose mat/panel which is not intended for use as an airfield surfacing should have a weight less than that of landing mat and desirably not greater than 3.0 lb per sq ft.

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* A table of factors for converting U. S. customary units of measurement to metric (SI) units is presented on page 4.

Definition of Pertinent Terms

4. For information and clarity, certain terms used in this report are defined as follows:

Test section: A prepared area on which the general-purpose mat/panel materials were placed for test purposes.

Subgrade: The portion of the test section constructed with soil upon which the general-purpose mat/panel materials were placed.

CBR (California Bearing Ratio): A measure of the bearing capacity of the soil based upon its shearing resistance. CBR is calculated by dividing the unit load required to force a piston into the soil by the unit load required to force the same piston the same depth into a standard sample of crushed stone and multiplying by 100.

Test vehicle: M54, 6x6, 5-ton military cargo truck (loaded with 20,000-lb payload and tire-inflation pressure of 70 psi) used in traffic tests. The total gross weight of the vehicle was approximately 40,000 lb.

Wheel path: Area of test section that right or left wheels of the test vehicle traversed as the test vehicle moved over the test section.

Load wheel: Wheels of the test vehicle that supported the major portion of the payload.

Pass: One trip of the test vehicle across the test section.

H-section: A special extruded aluminum adapter used to complete a junction between two items which had connectors that were dissimilar.

Lateral shifting: Movement of the panel left or right with respect to the length of the test section.

Transverse dishing (with reference to traffic): Permanent bending of a panel parallel to the direction of traffic.

Longitudinal dishing (with reference to panel): Permanent bending of a panel perpendicular to the direction of traffic.

PART II: DESCRIPTION OF TESTS AND EQUIPMENT

Traffic Tests

Test section

5. The test section for the traffic tests was located in an open unprotected area. An area approximately 40 ft wide and 125 ft long was required for the construction of the test section, which was 15 ft wide and 75 ft long (Plate 1). Sand (SP, Plate 2) was placed on the test section with a front-end loader and smoothed by a D4 dozer to a depth of 12 in. This sand was surrounded by clay shoulders (Figure 1). The

Figure 1. Test section prior to panel placement

section was sloped slightly from the west to the east end. Prior to the placement of clay soil at the east end of the section, a French drain was installed to allow any excess water from the natural elements

to drain from the test section. The sand at each end of the test section was overlaid with landing mat to provide approaches to the test section on which the general-purpose mat/panel materials were subjected to traffic testing. A typical test section prior to traffic testing is shown in Figure 2. Twelve-foot-long aluminum H-sections, 6 in. wide and

Figure 2. Typical test section with four test items

with a 1-3/4-in. opening (Figure 3), were used to join the approach mat

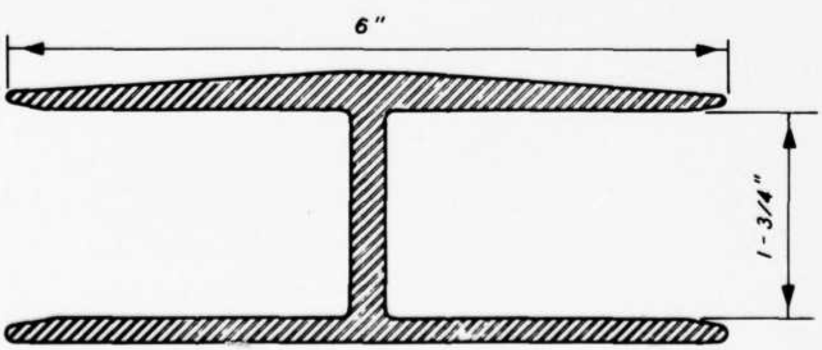

Figure 3. H-section

to the various items in each test section. These H-sections were also used not only to join the different items together but to join panels of the same item where the individual panels did not contain side connectors. Wooden shims were used with panels which were not thick enough to fill the opening in the H-sections.

Test vehicle

6. A 5-ton, 6x6, M54 military cargo truck with winch, loaded to 20,000 lb (gross weight, 40,000 lb), was used as the primary test vehicle in the traffic tests (Figure 4). The 11x20, 12-ply tires

Figure 4. View of 5-ton, 6x6, M54 winch truck loaded to 20,000 lb (gross weight, 40,000 lb)

were inflated to 70 psi. A layout of the wheel spacing of the test vehicle is shown in Figure 5.

Application of traffic

7. Traffic was applied in a channelized pattern similar to that which would be encountered in actual road conditions. The 12-ft-long

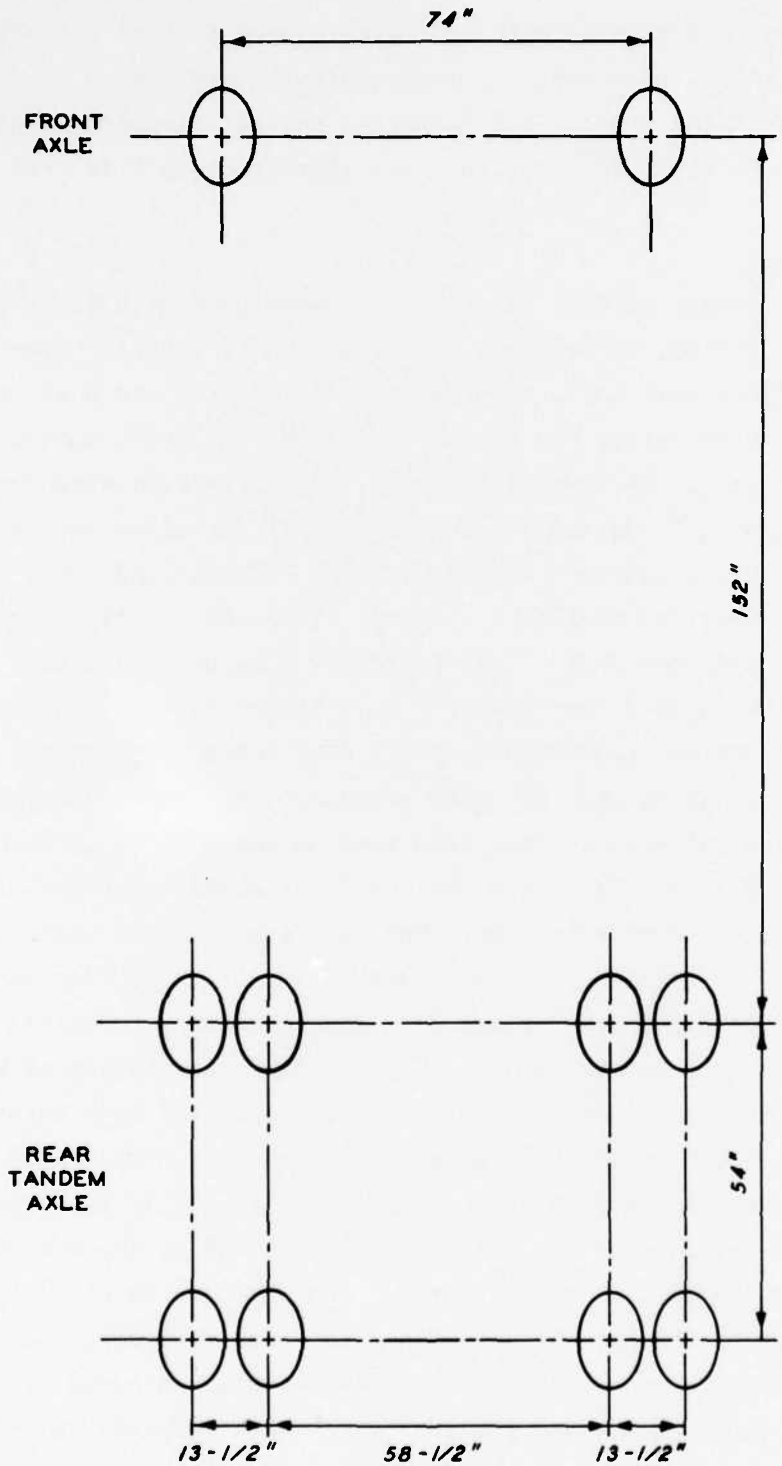

Figure 5. M54 cargo truck
wheel configuration

general-purpose mat/panel materials were placed to form a 12-ft-wide section or they were trafficked longitudinally and spaced to fit the wheel paths of the truck. The 8-ft-long general-purpose mat/panels were placed so that one wheel path was approximately 2 ft from the panel ends.

Data recorded

8. A summary of CBR, density, and water content data taken prior to traffic testing, at failure, and/or at end of tests is presented in Table 1. These soil tests were made at depths of 0 and 6 in. with a minimum of three values per depth. Data for four test sections are given in Table 1. For report purposes, these sections were designated test sections 1, 2, 3, and 4. Test section 1 contained four mat/panel materials: Wells extruded aluminum, Taber extruded aluminum, Fletcher formed aluminum, and M8A1 rolled steel. This test section was located between sta 0+00 and 0+75. Test section 2 also contained four items: M. C. Gill balsa wood core aluminum skin sandwich, 2.5- and 3.0-lb-per-sq-ft Kaiser aluminum honeycomb core and skin sandwich, and Alcoa extruded aluminum. The sand subgrade was reprocessed prior to testing these materials. This test section was located between sta 0+15 and 0+75 (Plate 1). Test section 3 contained two types of Spur-Ecolite aluminum core materials. The sand subgrade was again reprocessed prior to testing these materials. This test section was located between sta 0+45 and 0+75 (Plate 1). Test section 4 contained the Woodside formed aluminum panels. The subgrade for testing this material was a dry loose sand spread on the test section with handtools. This test section was located between sta 0+51 and 0+63 (Plate 1). The CBR of the sand surface prior to traffic was generally less than 2 and that at the 6-in. depth was less than 4. The CBR at the end of traffic varied from 1.5 to 13.7 at the surface and from 3.4 to 16.7 at the 6-in. depth. Some of the materials confined the sand subgrade, thus enabling the subgrade strength to increase; other materials allowed the subgrade to migrate beneath them and the strength of the subgrade did not increase as much. The subgrade for the remaining materials tested was processed in a manner similar to that for the four sections mentioned above.

9. Generally, level readings of cross-section and profile data were taken prior to, during, and at the conclusion of traffic to measure permanent deformation. Visual observations of the materials and subgrade behavior were recorded throughout the period of traffic and were supplemented by photographs.

Laboratory Tests

Rigidity test

10. The purpose of this test was to determine the ability of the general-purpose mat/panel to perform as a beam when used as a structural member, such as in floors, roofs, walkways, etc. A simple beam test was conducted with the load concentrated at the one-third points of the span (Figure 6). Full-size panels were tested and the deflections at the midpoint up to a maximum of 4 in. and the corresponding loads were continually recorded on an electric recorder. The laboratory test results and other pertinent data are given in Table 2.

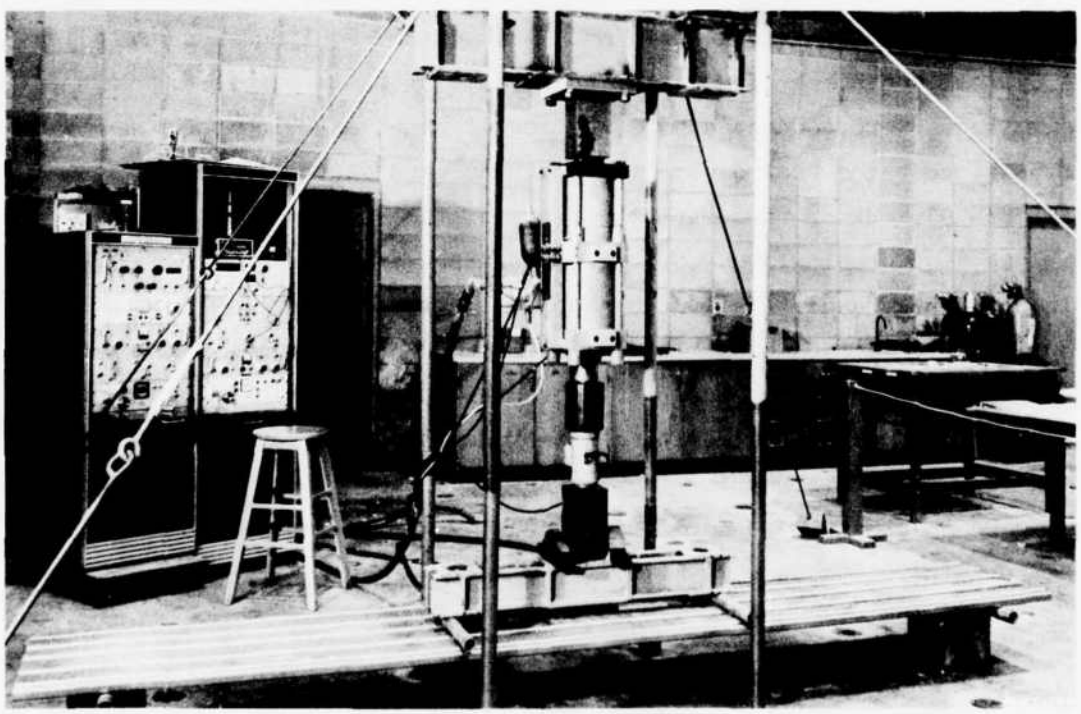

Figure 6. Setup for rigidity test

Buckling test

11. The purpose of this test was to determine the ability of the general-purpose mat/panel to perform as a vertical column when used as a structural member such as in walls for buildings, revetments, etc. The load was applied at the ends of the panels (Figure 7). Full-length panels were used in conducting these tests. Panels which were 4 ft wide were sectioned down the middle to make a 2-ft-wide panel for testing. Data for panels that were less than 12 ft long were converted to data corresponding to a 12-ft-long panel for comparison. Lateral midpoint (length) deflection was measured continuously with corresponding load up to a maximum of 4-in. deflection on an electric recorder. Initial preliminary assumptions were that a lateral deflection of 4 in. was the maximum that could be tolerated in a revetment-type structure in the field.

Crush resistance test

12. The purpose of this test was to determine the crush resistance of the general-purpose mat/panel when used as a surfacing for containers such as are used in mass movement of equipment and supplies.* A typical container corner bearing foot is shown in Figure 8. Compressive tests were conducted on a section of panel in which the 6.5- by 8.5-in. container corner bearing foot was used as the loading head (Figure 9). Since the contact surface of the bearing foot contained an oblong slot opening, the approximate contact area was 40 sq in. The load was recorded at failure as applicable up to a maximum load of 50,000 lb. The 50,000-lb loading represented the maximum load of one bearing foot on a container if the containers were stacked two high and fully loaded with consideration given that the load may not be equally distributed on all bearing feet. Thus, a crushing load of 1250 psi or more on a panel was more than adequate in representing the loadings of containers stacked two high.

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* Headquarters, Department of the Army, "Army Transportation Container Operations," Field Manual No. 55-70, 17 Feb 1975, Washington, D.C.

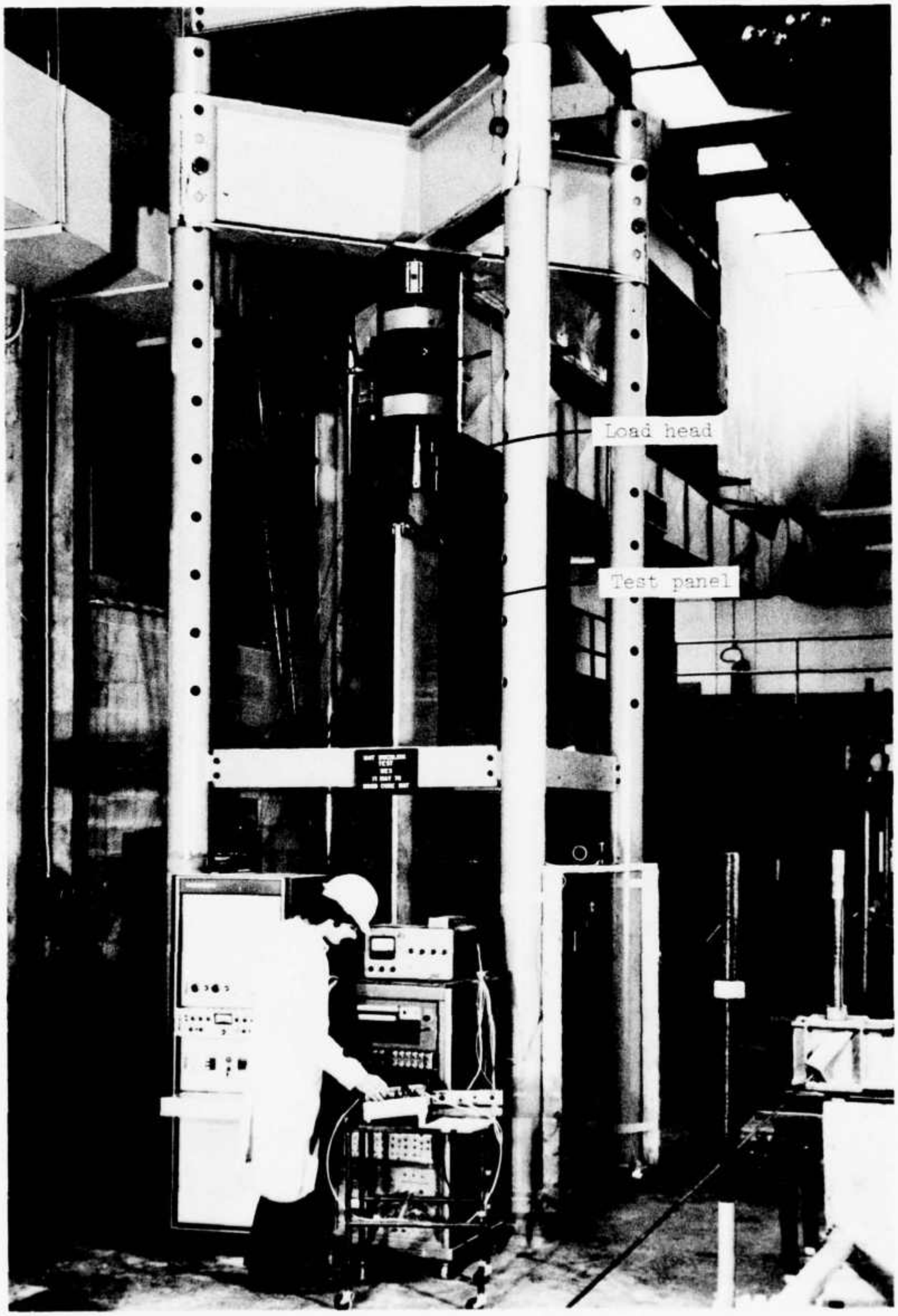


Figure 7. Setup for buckling test

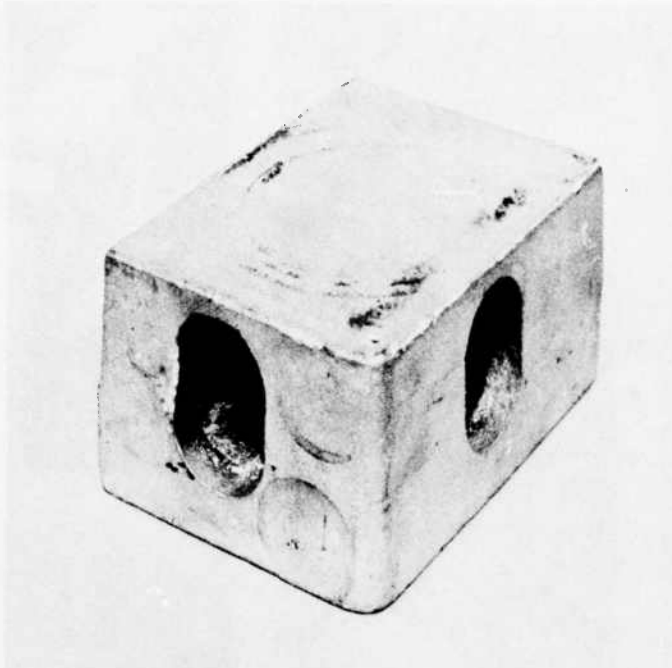


Figure 8. Container corner bearing foot used in crush resistance test

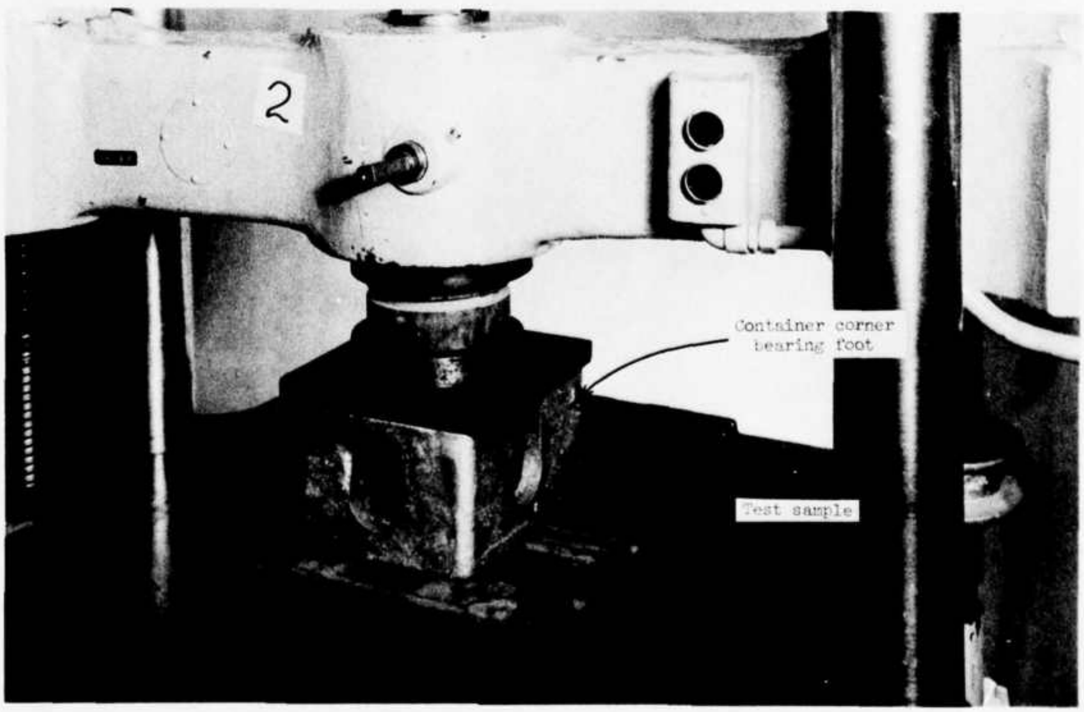


Figure 9. Setup for crush resistance test

PART III: DESCRIPTION, TESTS, AND RESULTS OF MAT/PANEL MATERIALS

Wells Extruded Aluminum

Fabrication features

13. The Wells extruded aluminum panels were designed and extruded by Wells Aluminum Corporation, North Liberty, Ind. The individual panels are one-piece, multihollow, 6105-T6 aluminum alloy extrusions 0.89 in. thick, 9.64 in. wide, and 12 ft long and have a weight of 3.2 lb per sq ft of placing area (Figure 10). The panels interlock

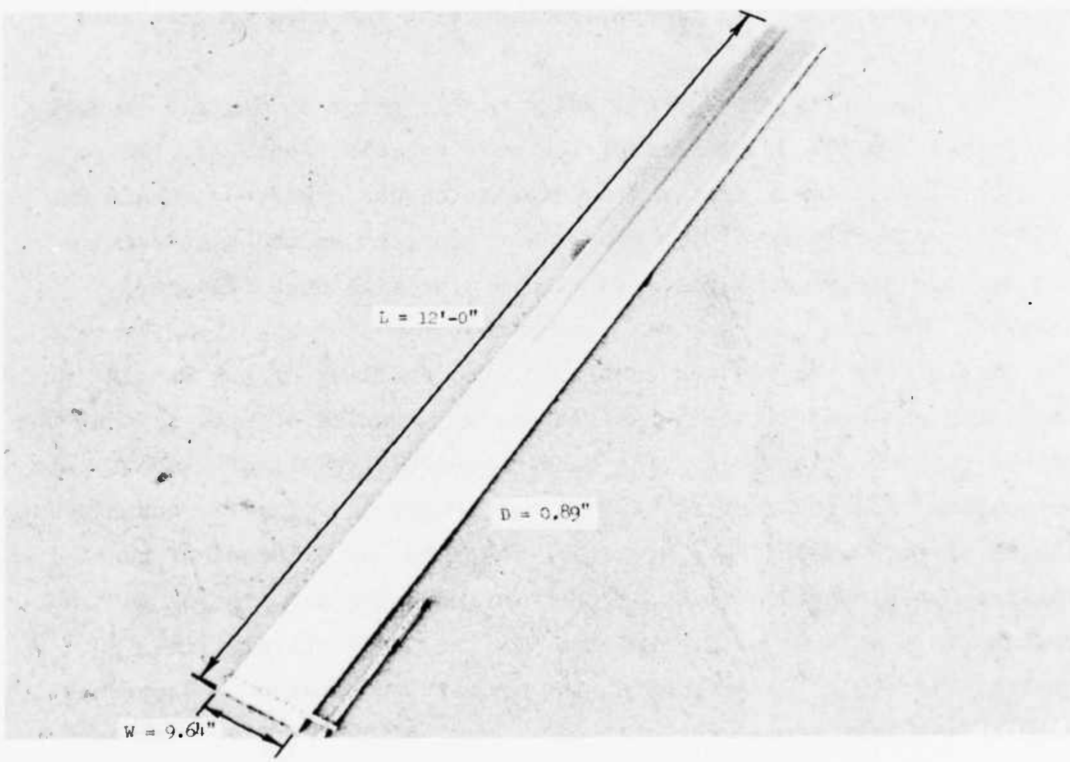


Figure 10. Wells extruded aluminum panel

along the sides by means of a hinge-type connector, the components of which are integral parts of the panel extrusion. There are no connectors on the ends of the panels. Individual panels weigh only 28.5 lb and can be placed by one person.

Traffic tests

14. The Wells extruded aluminum panels were item 1 of test section 1. The length of this item was 20 ft with 27 panels placed for traffic testing. The first panel was placed on the section and connected to the approach mat by means of the H-section. After this panel was placed, the next panel to be placed was joined by means of the side connectors. The second panel was held at approximately a 45-deg angle with the first panel. The female connector of the second panel was engaged with the male connector of the first panel and with a downward hinging action of the second panel, this panel was secured in place on the test section. The remaining panels were placed in a similar manner. After the last panel was placed, an H-section was used to join this item with item 2.

15. A general view of the Wells panels prior to traffic is shown in Photo 1. After 200 passes of the test vehicle (Photo 2), the panels were still relatively flat and no distortion was observed. There was some lateral shifting of the panels with respect to the test section and to each other. The cross-section and profile data (Plate 3) revealed that the subgrade was consolidating and/or migrating beneath the panels. As traffic was continued, the shifting of the panels continued and several times traffic was temporarily stopped so that the panels could be realigned. The panels remained relatively smooth with no rutting or dishing after 2000 passes (Photo 3). Traffic was discontinued after 3000 passes (Photo 4). There was no evidence of panel failure nor distortion although the cross-section and profile data had changed to a maximum of 1.3 in. and 1.4 in., respectively, in 3000 passes (Plate 3). Data taken at the transition between the approach mat and the test items were not used. During the traffic, some sand particles had entered the connectors of the panels and this sand under the action of the test vehicle had caused some abrasive wear on the connectors. However, this did not cause any detrimental effects on the panels in that their overall condition was very good and the panels were capable of sustaining additional traffic.

Laboratory tests

16. A full panel, 9.64 in. wide by 12 ft long, was tested as a column in the buckling tests. In three tests, an average load of 2667 lb or 3560 lb per foot of width (Table 2) was required to buckle the panel. After the load was released, there was no permanent set in the panel. In the rigidity test, a full panel was used with a 10-ft beam span with one-third point loadings. A load of 225 lb or 300 lb per foot of width (Table 2) was required to deflect the panel 4 in. at the midpoint. After the load was removed, there was no permanent set in the panel. A load-deflection curve is given in Plate 4. A specimen from a Wells panel withstood 50,000 lb or 1250 psi (Table 3) in the crushing test with no failures or indentation of the surfaces of the specimen.

Analysis of results

17. The performance of the Wells extruded panels under traffic was excellent in that the panels sustained 3000 passes with only minor wear on the connectors. This wear was caused by the abrasive action of the sand migrating in the connectors. The panels were capable of sustaining many more passes of the test vehicle; however, traffic was stopped because of the time and cost that would have been involved in applying additional traffic, and it was decided that the 3000 passes would be an arbitrary data point to compare all mat/panels. The Wells panels were 0.2 lb per sq ft overweight; however, the panel, especially in the hinge-type connectors, could probably be redesigned in order to reduce the weight to within the specified maximum weight without affecting the performance of the panels. In the laboratory tests (Tables 2 and 3), the values obtained for the Wells panels in the rigidity and buckling tests were among the lowest of the values obtained for the nine different materials subjected to these tests. However, the crushing strength value was one of the highest obtained. The Wells panels should be considered for further evaluation even though in their present design they are slightly overweight. Their performance in the traffic tests and crushing tests was exceptional. These are two important tests for determination of the suitability of the panels for use in movement of material, supplies, and personnel as well as for

use as flooring for storage sites for materials and supplies. The cost of the Wells extruded panels should be much lower in quantity procurements than that for the experimental test quantity procured for this investigation.

Taber Extruded Aluminum

Fabrication features

18. The Taber extruded aluminum panels were designed and extruded by Taber Metals, Inc., Russellville, Ark. The individual panels are multihollow, 6063-T5 aluminum alloy extrusions, 1.0 in. thick, 24 in. wide, and 12 ft long, and have a weight of 2.8 lb per sq ft of placing area (Figure 11). The panels connect along the sides by means of

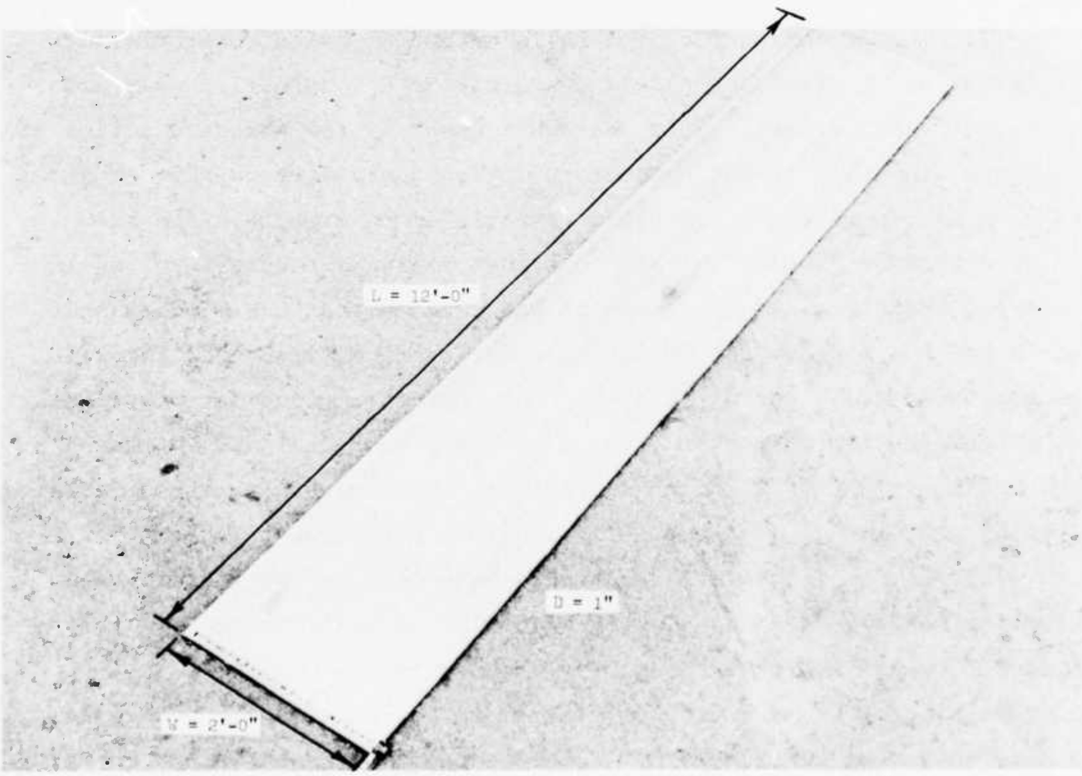


Figure 11. Taber extruded aluminum panel

tongue-and-groove connectors, the components of which are integral parts of the panel extrusion. In order to prevent the panels from

separating, 1/4-in. aluminum drive rivets were installed on 12-in. centers along the tongue-and-groove connectors. There were no end connectors on the panels. Individual panels weigh 66 lb and can be placed by one person.

Traffic tests

19. The Taber extruded aluminum panels were item 2 of test section 1. The length of this item was 20 ft with 10 panels placed for traffic testing. The first panel was placed on the section and connected to item 1 by an H-section. After this panel was placed, the groove of the second panel was placed over the tongue of the first panel. Then 1/4-in.-diam drive rivets on 12-in. centers were installed to hold the panels together for traffic testing. The remaining panels were placed in a similar manner. After the last panel was placed, an H-section was used to connect this item to item 3.

20. A general view of the Taber panels prior to traffic is shown in Photo 5. As traffic was applied, some lateral shifting of all Taber panels occurred, since each panel was fastened to the adjoining panels with rivets. Several times during the period of test, traffic was temporarily stopped in order to realign this item on the test section. Photo 6 is an overall view of the panels after 200 passes of traffic. Although the surface of this test item remained relatively smooth, the panels contained a 1/8-in. maximum longitudinal dishing after 500 passes. Popping noises were noted at 677 passes. These noises, which indicated some type of internal failure, were present in both wheel paths of the test vehicle. Slight dimpling in the surface of several of the panels was also observed. The popping noise continued throughout the remainder of the test. At 1000 passes, the Taber panel next to the H-section which connected this item to item 3 was removed for inspection. There was one broken vertical rib in this panel in each wheel path of the test vehicle. The rib was broken at the intersection of the rib and the top sheet of the panel. Since there were no tire hazards and the longitudinal dishing in the panels was only a maximum of 1/8 in., the panel was reinserted and traffic was continued. At 1500 passes, the top sheets of three panels in both wheel paths were

separated from all the vertical ribs except the ones next to the connector. The surface across the width of the panel was irregular due to the broken ribs. The female lip of these same three panels had separated from the vertical panel rib at 1830 passes. Two of the panels had developed 1-in.-long splits in the top skin which ran parallel with the panel widths. The rivets prevented complete separation of the skin from the panels in the wheel paths of the vehicle. The panels after 2000 passes are shown in Photo 7. Several areas where the top skin is separated from the vertical ribs are shown circled in this photograph. Transverse dishing at that time is shown in Photo 8; the maximum measured was 1/2 in. Traffic was then continued to 3000 passes (Photo 9). Longitudinal dishing of 1-3/8 in. was measured when traffic was stopped. The maximum change in cross section from beginning of traffic to 3000 passes was 1.4 in. and the maximum change in profile was 1.6 in. (Plate 5). After the panels were removed from the test section, a sample of panel 33 was cut (Photo 10) from the south wheel path. Although the surface of the panels was rough due to dishing caused by internal rib failure, the panels could have supported additional passes of the test vehicle.

Laboratory tests

21. A full panel, 24 in. wide by 12 ft long, was tested as a column in the buckling tests. In three tests, an average load of 7833 lb or 3920 lb per foot of width (Table 2) was required to buckle the panel. In the rigidity test, a full panel was used with a 10-ft beam span with one-third point loadings. A load of 880 lb or 440 lb per foot of width (Table 2) was required to deflect the panel 4 in. at the midpoint. After the load was removed, there was no permanent set in the panel. A load-deflection curve is shown in Plate 4. A specimen from a Taber panel withstood 50,000 lb or 1250 psi (Table 3) in the crushing test. The top surface of the specimen was depressed 3/16 in. under the container corner.

Analysis of results

22. The Taber panels sustained 3000 passes of the test vehicle; however, internal deterioration of the panels was observed at 677 passes.

Popping noises which indicated internal rib failure were heard at this passage level and the failure was confirmed at 1000 passes when a panel was removed from the test item and examined. In the laboratory tests (Tables 2 and 3), the values obtained for the Taber panels in the rigidity and buckling tests ranked fifth and sixth, respectively, in a total of nine different materials subjected to these tests. The value for the crushing strength tests was one of the highest obtained. For the traffic tests, the panels were secured together along the sides with drive rivets. For rapid installation for field use of panels such as these, drive rivets are not considered a desirable method of fastening the panels. Since the weight (2.8 lb per sq ft) of the panels was less than the maximum (3.0 lb per sq ft), the connectors could be redesigned to eliminate the need to use drive rivets for securing the side connectors together. The Taber panel in its present configuration should not be considered for further evaluation as a general-purpose mat/panel.

Fletcher Formed Aluminum

Fabrication features

23. The Fletcher formed aluminum panels were designed and fabricated by the Sargent-Fletcher Company, El Monte, Calif. The panels were fabricated from 0.1-in.-thick, 6061-T4 aluminum alloy by using the break press method. The individual panels are 1.5 in. thick, 22 in. wide, and 12 ft long and have a weight of 2.1 lb per sq ft of placing area (Figure 12). The side connectors are an integral part of the basic panel in that the grooves of one panel overlap that of the next panel, and spring clips fit in slots in these grooves to fasten the panels together. Six clips are required for each panel. Matching slots are incorporated in the panels and when the edge groove of one panel is placed over the edge groove of the next panel and the slots aligned, the spring clips are installed to lock these panels together. Individual panels weigh 43.3 lb and can be placed by one person.

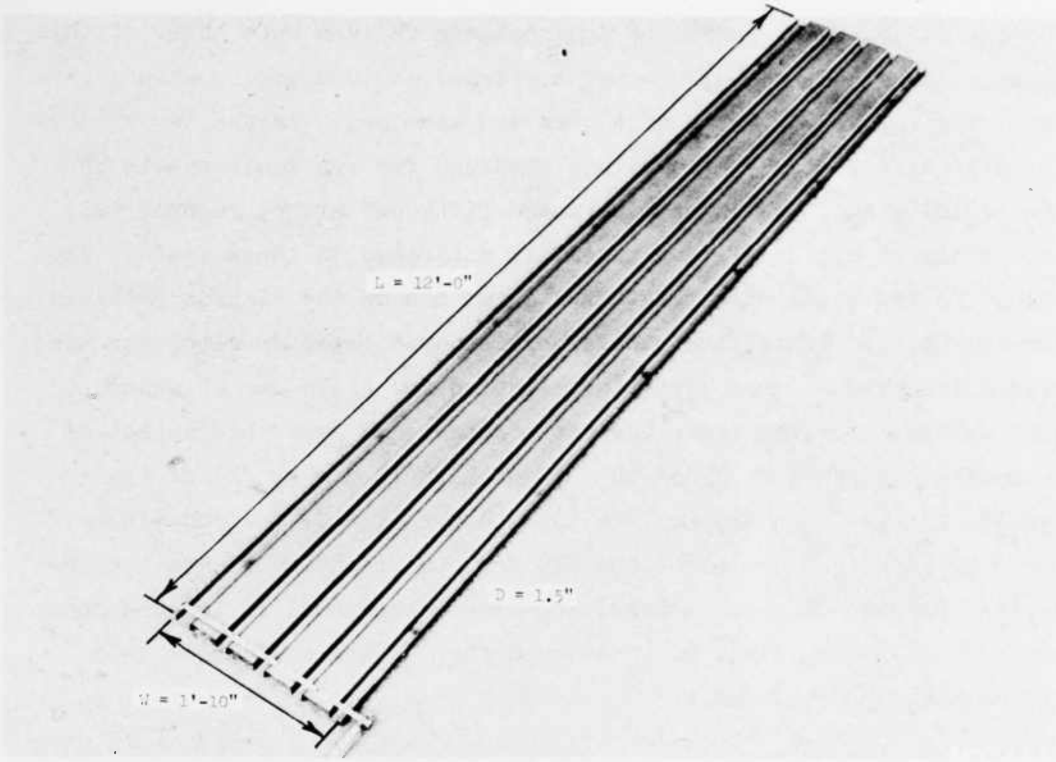


Figure 12. Fletcher formed aluminum panel

Traffic tests

24. The Fletcher formed aluminum panels were item 3 of test section 1. The length of this item was 20 ft with 11 panels placed for traffic testing. The first panel was placed on the section and one side of the panel was connected to item 2 by an H-section. After this panel was placed, the second panel was placed with the groove of this panel placed over the edge groove of the first panel. The clip holes of panels 1 and 2 were aligned and the clips were installed. The tabs of the clip were bent to prevent them from coming out and allowing the panels to separate. The remaining panels were placed in a similar manner. After the last Fletcher panel was placed, an H-section was used to connect this item to item 4.

25. A general view of the Fletcher panels prior to traffic is shown in Photo 11. The panels moved some during the first few passes. This movement was a wave-type action across the width of the panels. After 20 passes, the panels seated themselves on the test section.

The panels began to dish longitudinally after the first few passes and at 200 passes (Photo 12), a maximum of 2-5/8-in. longitudinal dishing was measured. Photo 13 shows the south edge of the panels at that time. (Note that the panel ends were off the subgrade.) At 200 passes, sand had pumped up through the edge connectors and holes where the spring clips had been installed. The sand also had migrated out from under the ends of the panels. As traffic was continued, some lateral shifting of all the panels occurred. Several times during the period of test, traffic was temporarily stopped in order to realign this item on the test section. The sand continued to migrate from beneath the edges of the panels (Photo 14) as traffic was continued to 1000 passes. Dishing of the panels had increased to a maximum of 3-9/16 in. The sand continued to be pumped through the side connectors and holes where the clips were installed as shown at 2000 passes in Photo 15. Several of the panels showed evidence (Photo 16) of separating along the connectors at the spring clips. The panels were not dished as much after 2000 passes (3-1/4 in.) as they were after 1000 passes (3-9/16 in.). After 2500 passes, a 1-in. split in panel 43 at the second clip hole in from the north end of the panel had occurred. This split ran parallel with the panel width. As traffic continued this split grew in length. Splits were also observed in all the other Fletcher panels at the second connector clip hole from the north edge of the panels. These clips were in the wheel path of the test vehicle. Traffic was stopped after 3000 passes (Photo 17). Longitudinal dishing of the panels was 3-5/8 in. The ends of the panels had remained off the sand subgrade (Photo 18). The split in panel 43 had grown from 1 to 9 in. (Photo 19). A split had also developed in the adjacent panel 44 next to the split in panel 43. The surface of the panels parallel to the width of the panels was relatively smooth when traffic was stopped. The maximum change in cross section from beginning of traffic to 3000 passes was 3.9 in. and the maximum change in profile was 2.2 in. (Plate 6). Except for the possible tire hazard caused by the split in panel 43, the other panels could have supported additional passes of the test vehicle.

Laboratory tests

26. A full panel, 22 in. wide by 12 ft long, was tested as a column in the buckling tests. In three tests, an average load of 7700 lb or 4200 lb per foot of width (Table 2) was required to buckle the panel. After the load was released, there was no permanent set in the panel. In the rigidity test, a full panel was used with a 10-ft beam span with one-third point loadings. A load of 700 lb or 390 lb per foot of width (Table 2) was required to deflect the panel 4 in. at the midpoint. After the load was removed there was 1 in. of permanent set in the panel. A load-deflection curve is shown in Plate 4. A specimen from a Fletcher panel withstood 9300 lb or 233 psi (Table 3) in the crushing test but the panel specimen was deformed or compressed.

Analysis of results

27. The performance of the Fletcher panels under traffic was not as good as that of several of the other materials. The individual panels were longitudinally dished as much as 3-5/8 in. at the completion of 3000 passes. The cross-section and profile data (Plate 6) confirm not only longitudinal dishing but transverse dishing. After 3000 passes, a tire hazard was present due to the split in panel 43 and adjacent panel 44 which originated at the spring clip holes in these panels. In the laboratory tests (Tables 2 and 3), the values obtained for the buckling and rigidity tests ranked fifth and seventh, respectively, in a total of nine different materials subjected to these tests. The value for the crushing test was the lowest obtained in a total of ten materials subjected to this test. Since the Fletcher panel did not perform in the traffic tests without distortion and panel splitting and since the laboratory strength values were lower than those for several other materials investigated, no further evaluation of these panels in their present form is recommended.

M8A1 Rolled Steel

Fabrication features

28. The M8A1 panels used in this test were secured from military depot storage. The individual panels were fabricated from carbon steel

sheets (per QQ-S-640), 0.125 in. thick, by a roll and break press method. The side connectors and slots for the connectors were stamped prior to the roll and press operation. The panels also contain end connectors which consist of steel bars and cover plates. Each panel is 1-1/8 in. thick, 19-1/2 in. wide, and 11 ft 9-3/4 in. long, and has a weight of 7.5 lb per sq ft of placing area (Figure 13). Individual

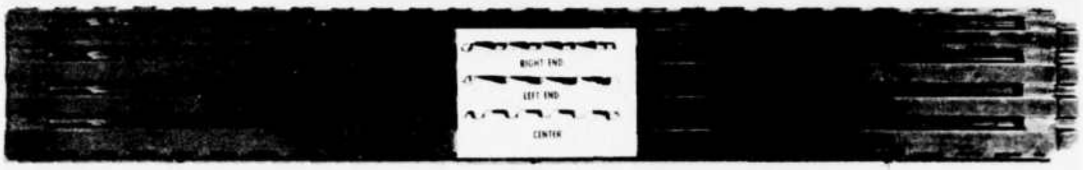


Figure 13. M8A1 rolled steel panel

panels weigh 144 lb and can be placed by two people. These panels were designed to support aircraft wheel loadings; however, due to the low cost ($1.06 per sq ft) and availability, they have been used in many other applications in the theater of operations.

Traffic tests

29. The M8A1 rolled steel panels were item 4 of test section 1. The length of the item was 15 ft with nine panels placed for traffic testing. The first panel of M8A1 was connected to item 3 by means of an H-section. During placement the second panel was held at approximately a 45-deg angle with the first panel. The connector hooks of this panel were engaged in the slots of the first panel. The second panel was slid about 1 in. with respect to the first panel and then dropped onto the test section. The other panels were placed in a similar manner. The last panel placed was joined onto the approach mat with an H-section.

30. A general view of the M8A1 panels prior to traffic is shown in Photo 20. As traffic was applied, the surface of the M8A1 remained relatively flat although some sand was pumped up through the connectors and out from under the ends of the mat. Some lateral shifting of the

panels occurred and all panels moved together since they were locked together by the slots and hooks of the side connectors. The panels after 200 coverages are shown in Photo 21. As traffic was continued, some longitudinal dishing of the panels was observed in the wheel paths of the test vehicle. The panels were realigned in the test section several times due to shifting under the wheels of the test vehicle. Traffic was discontinued after 3000 passes (Photo 22). Although longitudinal dishing of 1/4 in. was measured in the wheel paths at this time, no distress was observed in the panels. The maximum change in cross section from beginning of traffic to 3000 passes was 1.6 in. and the maximum change in profile was 1.8 in. (Plate 7). The overall condition of the M8A1 panels at the end of 3000 passes was very good and they were capable of withstanding additional traffic .

Laboratory tests

31. A full panel, 19-1/2 in. wide by 141-3/4 in. long, was tested as a column in the buckling tests. In three tests, an average load of 8400 lb or 5310 lb per foot of width (Table 2) was required to buckle the panel. After the load was released, there was no permanent set in the panel. In the rigidity test, a full panel was used with a 10-ft beam span with one-third point loadings. A load of 1200 lb or 760 lb per foot of width (Table 2) was required to deflect the panel 4 in. at the midpoint. After the load was removed, there was 1-1/2-in. permanent set in the panel. A load-deflection curve is shown in Plate 4. A specimen from an M8A1 panel withstood 42,500 lb or 1063 psi (Table 3) in the crushing test. The surface of the specimen was deformed.

Analysis of results

32. The performance of the M8A1 panels under traffic was excellent in that the panels sustained 3000 passes with only minor longitudinal dishing of the panels. In the laboratory tests (Tables 2 and 3), the values obtained from the rigidity and buckling tests ranked first and third, respectively, of a total of nine materials subjected to these tests. The value obtained for the crushing ranked seventh in a total of ten materials subjected to this test. Although the M8A1 panels performed well in the tests conducted and the cost per square

foot is the lowest of all materials tested, no further testing as a general-purpose mat/panel is recommended since the weight, 7.5 lb per sq ft, is more than twice the maximum permissible weight (3.0 lb per sq ft).

M. C. Gill Aluminum/Balsa Wood Sandwich Panel

Fabrication features

33. The sandwich panel (Figure 14) dimensions and weight were 144-1/8 in. by 48-1/8 in. by 1.09 in. and 93 lb, respectively, or an

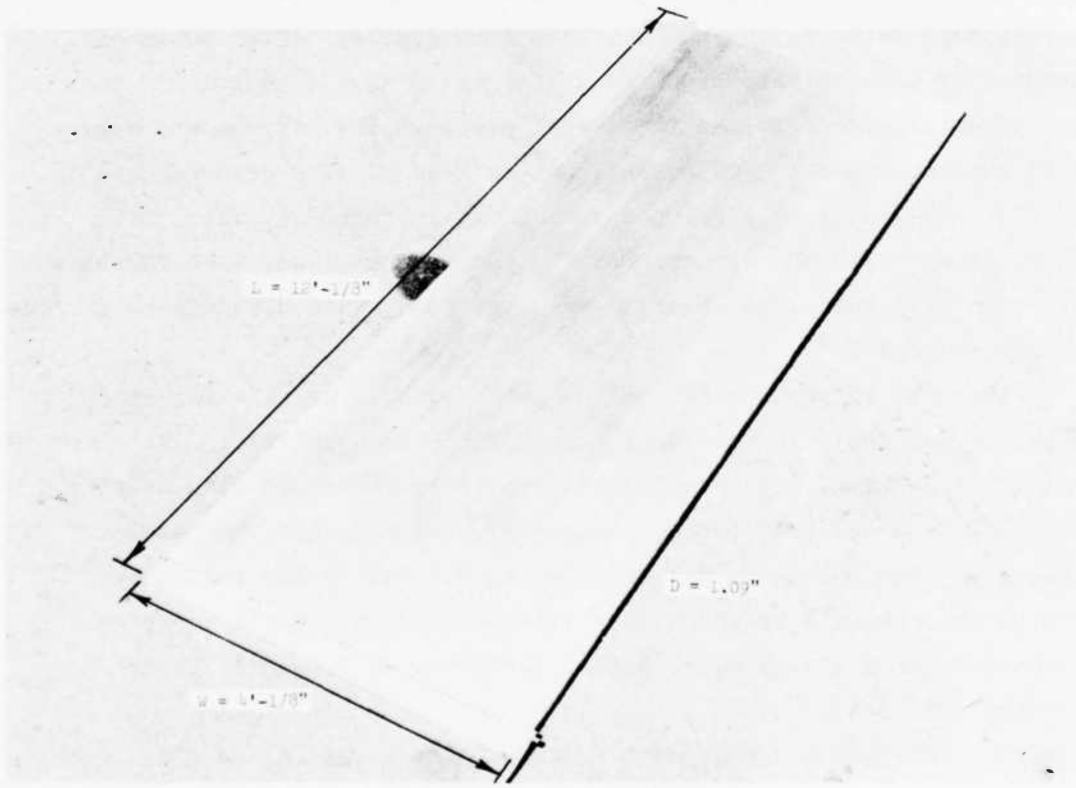


Figure 14. Gill aluminum sandwich, balsa wood core panel

average weight of 1.9 lb per sq ft (Table 2). The 1-in. core was of end grain balsa wood with an average density of 9.5 pcf. The top and bottom skins were 0.040-in.-thick sheets of aluminum alloy 6061-T6 and were bonded to the core using epoxy adhesive. There were no connectors on any of the panel edges.

Traffic tests

34. The Gill aluminum/balsa wood sandwich panels were item 5 of test section 2. The panels were connected together and to adjacent panels in the mat approach and item 6 with H connectors, with wood shims used in the bottom of the H connectors to make the panels fit snug. Five panels were connected together to make a section 12 ft by 20 ft as shown in Photo 23. At the beginning of traffic the mats were generally smooth and remained smooth during the first 300 passes. At this point, however, as the load wheels passed over the mats, a popping noise was heard, and at 330 passes, panels 3 and 4 contained a slight depression in the paths of the load wheels. After 500 passes, tapping of the top skin produced a flat thump sound, indicating that the adhesive had disbonded in several places. The popping and depression continued and at 800 passes, panels 1 and 2 were deformed 1/4 in. in the 3-ft-wide load wheel paths as shown in Photo 24, which actually shows panel 3 at 1000 passes. As the panels depressed, disbondment was noted on all panels. As traffic was continued, this disbondment progressively increased.

35. After 1100 passes the top skin began to wrinkle or crease near the mat edges in the wheel paths of the test vehicle. The disbondment, deformation, and creasing progressively increased with traffic. Cross-section and profile data (plate 8) indicate that the panels generally embedded uniformly from 0.4 to 0.5 in. during the first 200 passes. Panels embedded very little thereafter until the panels began deforming in the wheel paths, producing an irregular cross section (Plate 8).

36. At 1600 passes, panel 1 had a 1-in. break in the south wheel path which progressed to 4-1/2 in. at 1720 passes. At 1900 passes, panel 4 had a 2-in.-long break. At 2000 passes, the item was considered failed as disbondment was extensive in both wheel paths. The section is shown at the completion of traffic (2000 passes) in Photo 25. Panels 1, 4, and 5 had top skin breaks, and panels 1, 3, and 4 had bottom skin breaks. The maximum length of breaks on the top and bottom was 5-3/4 in. Panel 4 was dissected to inspect the internal

core failure and adhesive failures (see Photo 26). Only about 5 percent of the bond of the specimen in Photo 26 had to be forced apart by hand as the other 95 percent had failed during the traffic test.

Laboratory tests

37. A specimen 2 by 12 ft was tested as a column. The average total load applied to the specimen in three tests was 5667 lb or 2834 lb per foot of width (Table 2). After the buckling load was released, the specimen returned to its original configuration with no permanent set. In the beam test with one-third point loading over a 10-ft span, the specimen withstood 245 lb per foot of width (Table 2) at a deflection of 4 in. (Plate 4) with no permanent set. In the crushing test under the container corner support, the specimen withstood 50,000 lb or 1250 psi (Table 3) with only a slight indentation of the specimen top skin at the edge of the container corner.

Analysis of results

38. The M. C. Gill panels started disbonding between 300 and 500 passes and progressively disbonded and became rougher with additional traffic. Breaks were noted in the top skin at 1600 passes and the item was considered failed at 2000 passes. At 1.9 lb per sq ft, the panels were the third lightest tested. The M. C. Gill panel was among the top four in crushing strength, but ranked last in both buckling and rigidity loading.

39. All edges of the wood core were exposed and susceptible to weathering. In designing edge connectors for the balsa wood panels, considerations would have to be given to making the edges waterproof and/or treating the wood to prevent deterioration of the core and adhesive.

40. At best, the panels' performance under traffic is considered marginal. Laboratory test results for buckling and rigidity were the lowest obtained, and these factors would eliminate further consideration for a balsa wood core material for a general-purpose mat.

Kaiser Aluminum Honeycomb Sandwich

General

41. Two mat designs were furnished WES for testing by Kaiser. The mats are similar in design and construction, but different skin thicknesses and core densities were used. Neither design had edge connectors, which when incorporated will increase the mat's weight slightly; however, edge members were used to seal and protect the honeycomb core. The mats tested were identified as 3.0 lb per sq ft and 2.5 lb per sq ft and are referred to hereafter as such in the text. However, their actual weights in pounds per square foot were 2.57 and 2.22, respectively, for the 3.0- and 2.5-lb panels. The skins on the 3.0-lb mats were 0.050 in. thick, and the honeycomb core had a density of 6.9 pcf. The core ribbons were 0.002 in. thick and were formed into 5/32-in. hexagon cells. The panel dimensions and weight were 8 ft 1/4 in. by 4 ft 1/4 in. by 1.49 in. and 83 lb, respectively (Figure 15).

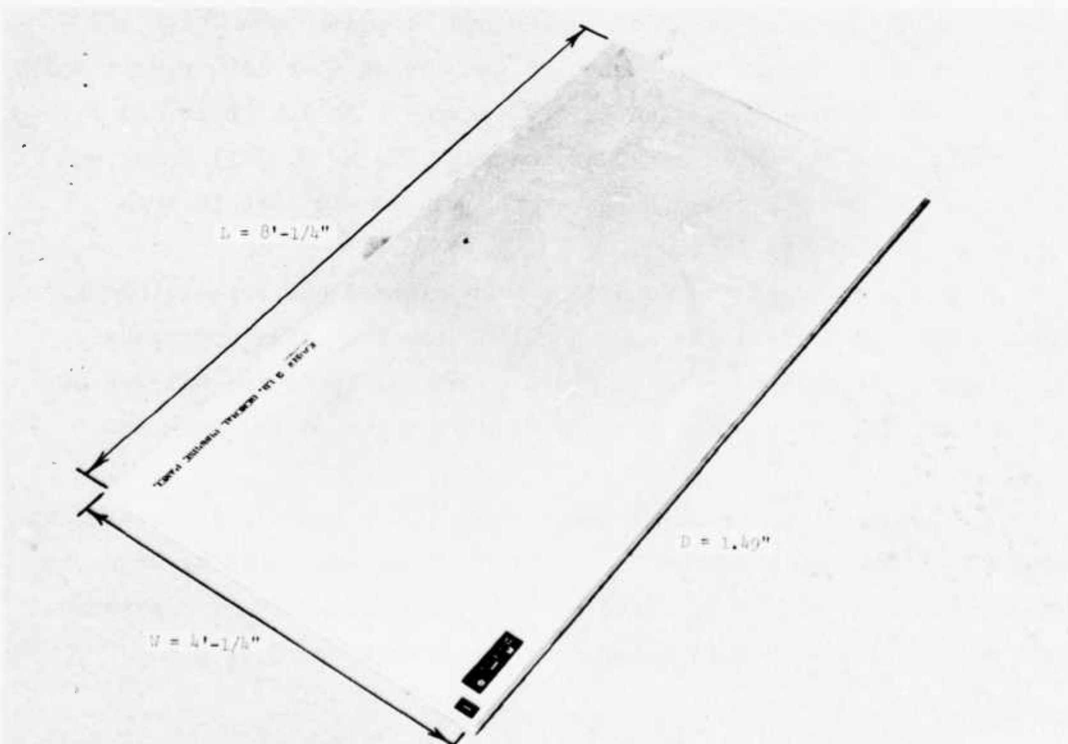


Figure 15. Kaiser 3.0-lb aluminum honeycomb sandwich panel

42. The 2.5-lb mats had 0.040-in.-thick skins, and the honeycomb had a density of 6.1 pcf. The 1/8-in. hexagon cells were formed with 0.0015-in. core ribbons. The overall panel dimensions and weight were 8 ft 1/4 in. by 4 ft 1/4 in. by 1.46 in. and 71.5 lb, respectively (Figure 16).

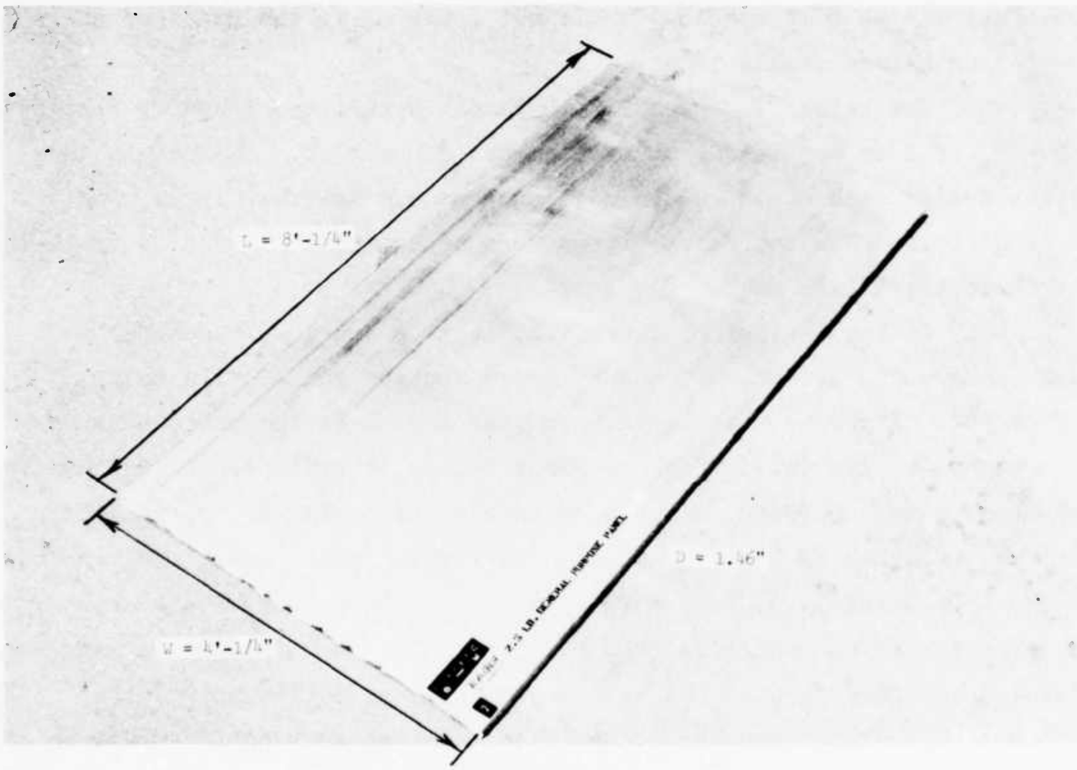


Figure 16. Kaiser 2.5-lb aluminum honeycomb sandwich panel

Fabrication features

43. The Kaiser mats are a sandwich honeycomb core construction. The skins are bonded to the core and edge members with Hexabond II adhesive. The adhesive is applied only to the core cell edges that contact the skin and to the top and bottom surfaces of the edge members. The sides of the edge members are bonded to the core with HP-106 adhesive, which will expand to four times its original size. The adhesives are activated and cured under elevated temperature and pressure.

Traffic tests

44. Five 3.0-lb panels were placed in the south wheel path so that one of the load wheels would track over them, and five 2.5-lb panels were placed in the north wheel path so that the opposite load wheel would traverse them (Photo 27). This was done so that the truck wheels (with an 8-ft spacing) would not track along the edges of the 8-ft-long Kaiser panels.

45. The Kaiser 3.0- and 2.5-lb panels were items 6 and 7, respectively, of test section 2. Each item was 20 by 8 ft. The panels were connected to each other and to adjoining panels in other items with H connectors. The two Kaiser items were separated 1 ft by a 1- by 12-in. by 14-ft board (see Photo 28).

46. At the beginning of traffic, items 6 and 7 were generally smooth as shown by Photo 27 and by cross-section and profile data (Plate 9). After 50 passes, anchors were driven at the outer ends of the panels to prevent lateral movement caused by traffic. At 200 passes, the panels had embedded in the sand fairly uniformly for approximately 0.5 in. as shown in Plate 9. Continued traffic only caused the mats to embed approximately 0.2 in. more (Plate 9). Items 6 and 7 are shown in excellent condition at 1000 passes in Photo 28. No distress or mat deformation was noted at this time. At 2000 passes (Photo 29) the items were still in excellent condition and they remained that way until the end of the test or 3000 passes (Photo 30). The panels were checked for flatness using a 4-ft straightedge in and around the load wheel paths. The 2.5-lb panels were flat within 0.20 in. and the 3.0-lb panels were within 0.010 in. of being flat. The traffic had caused no visible distress, deformation, or breaks of any type. One panel was dissected and the examination revealed no adhesive failures nor any indication of core failure.

Laboratory tests

47. The 3.0-lb specimen tested as a column was 2 by 8 ft. The 8-ft column withstood up to 35,800 lb while buckling less than 1 in. As further load was being applied, the specimen failed suddenly and had

a permanent set of 2 in. By Euler's formula,

$$\frac{P_c}{A} = \frac{\pi^2 E}{\frac{k^2 L^2}{r^2}}$$

where P_c = load, lb; A = area, sq in.; E = modulus of elasticity, psi; k = 0.5 (fixed ends); L = length, in.; and r = radius of gyration, in.

the load was converted to that for a 12-ft-long specimen, which is 15,760 lb, to compare with other specimens which were 12 ft long. The load per foot of width thus became 7880 lb (Table 2). The beam test was performed on a 2- by 8-ft specimen. The beam span was 6 ft 8 in. wide and the load was applied at the one-third points. For comparison purposes, the data were converted by means of the deflection formula to a beam span of 10 ft and are shown in Plate 4. At 4-in. deflection, the panel sustained 500 lb per foot of width (Table 2) and had a permanent set of 2-3/4 in. when the load was removed. Under the crushing test at 45,000 lb, or 1125 psi (Table 3), the core was depressed 1/4 in. and the skin was broken for 4 and 6 in. in two places along the edge of the head.

48. The 2.5-lb Kaiser panel was tested as a column also using a specimen 2 by 8 ft. The specimen sustained 27,000 lb and deflected less than 1 in. Additional loading caused the specimen to fail suddenly, leaving a permanent set of 2.6 in. This loading on an 8-ft specimen was also converted by Euler's formula to 11,980 lb on a 12-ft specimen or 5990 lb per foot of width to compare with similar data (Table 2). The beam test was performed on a specimen 2 by 8 ft using a span of 6 ft 8 in. and loaded at the one-third points. By using the deflection formula, the load was converted to a span of 10 ft for comparison (see Plate 4). The test specimen withstood 400 lb per foot of width (Table 2) at a deflection of 4 in. The top skin was creased across the width of the panel and embedded in the core to a depth of 1/4 in. under one of the one-third point loads. The panel had a

permanent set of 4-3/4 in. when the load was released. In the crushing test, the specimen sustained 1090 psi and failed by being compressed 1/4 in. (Table 3). The skin at the interior edge of the load head was broken for 3-1/2 in.

Analysis of results

49. The 3.0- and 2.5-lb Kaiser panels both withstood 3000 passes of the test vehicle. Both were in excellent condition at the end of the traffic test with no sign of stress or core bond degradation. The panels were within ± 0.020 in. of being flat when measured with a 4-ft straightedge. In the buckling test, the 3.0- and 2.5-lb panels were rated one and two, respectively, relative to the nine types of panels tested. In the rigidity test, the 3.0-lb panels were rated fourth and the 2.5-lb panels were rated sixth. The first and third rated materials in the rigidity test, M8A1 and Alcoa, were both overweight at 7.5 and 3.5 lb per sq ft, respectively. The fifth ranked Taber panel is 17 percent heavier than the light Kaiser panel (2.8 and 2.2 lb per sq ft, respectively) and produced a rigidity value only 10 percent greater than that of the lighter Kaiser panel.

50. Four of the materials tested sustained the maximum crushing load (1250 psi) or 10 and 13 percent more load than the two Kaiser panels (1125 and 1090 psi, respectively, for the 3.0- and 2.5-lb panels).

51. The test quantity cost of the Kaiser panels was more than that of most of the materials tested; however, the projected cost of a production buy would make the cost competitive at approximately $3.00 per sq ft or slightly less. The lighter Kaiser panel should be considered for further testing, assuming the cost can be in the range of $2.75 to $3.25 per sq ft in production quantities.

Alcoa Extruded Aluminum

Fabrication features

52. The Alcoa panels were extruded from 6061-T6 aluminum alloy. The overall panel dimensions and weight are 12 ft by 7-1/8 in. by

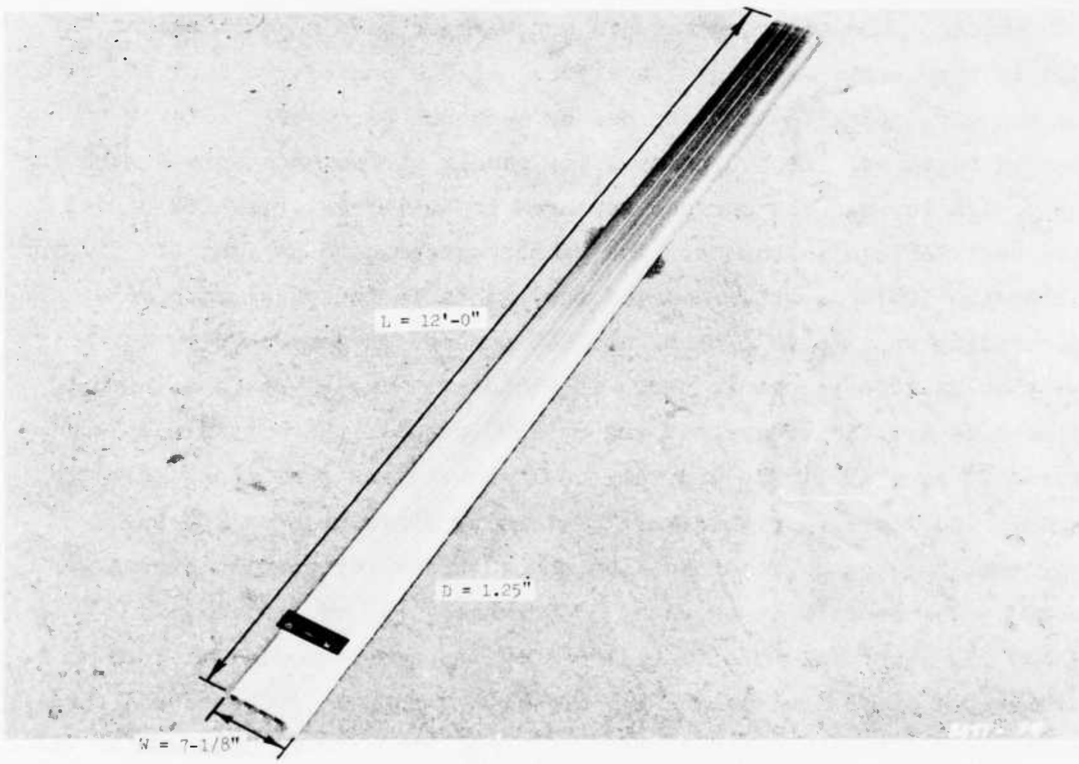


Figure 17. Alcoa extruded aluminum panel

3.5 lb per sq ft. The thickness of the top surface averaged 0.109 in. As the panels had no edge connectors, individual panels were connected for test with 1/4-in.-diam by 1-1/4-in.-long drive rivets. Matching holes on 12-in. centers were drilled along the 12-ft dimension near the edge. Four panels were riveted together as a unit prior to placing the mats for testing so that a minimum amount of riveting would have to be done in the field.

Traffic tests

53. The Alcoa panels were item 8 of test section 2. The item was 20 ft long by 12 ft. Prior to traffic the mat surface was generally smooth with a slight transverse slope to the north (Plate 10). A general view of the item prior to traffic is shown in Photo 31. The load wheels tended to make the panels work or disturb the subgrade sand. Plate 10 indicates that the mats had embedded in the sand subgrade

and/or the sand had consolidated an average of approximately 1 in. at 200 passes. The embedded mat did not work or move as much as the mat did in the earlier stages of traffic. At 500 passes, some of the rivets in the wheel path could be turned by hand but were still holding the panels together. At 800 passes, the panels at the ends were separating up to 1/4 in. and the surface appeared to be irregular, which caused the test vehicle to bounce. The panels appeared to be flat (no dishing) along the 12-ft length. Some of the rivets in the wheel path were protruding up 1/16 to 1/8 in. at 1000 passes. A general view of the section at 1000 passes is shown in Photo 32. The rivets continued to loosen as traffic progressed and at 2500 passes, the bottom end had worn off several rivets and they could be removed from their holes by hand. The loosened rivets were protruding up as much as 1/4 in. However, the panels remained flat and no breaks or panel distress was noted. The section is shown at 3000 passes (end of traffic) in Photo 33. Profile data (Plate 10) show the section only embedded an average of approximately 0.2 in. from 200 passes to 3000 passes. The section was still in good condition and no breaks were observed in the panels.

Laboratory tests

54. A full panel, 7.125 in. by 12 ft, was tested as a column. In three tests, an average load of 2230 lb or 3830 lb per foot of width (Table 2) was required to buckle the panels. When the load was released, the panel had a permanent set of 0.8 in. In the beam test, using a 10-ft span and one-third point loading, a load of 400 lb deflected the panel 4 in. This computes to 690 lb per foot of width (Table 2 and Plate 4). In the crushing test, the specimen withstood 50,000 lb or 1250 psi with no failure or indentation of the metal (Table 3).

Analysis of results

55. The Alcoa panels sustained 3000 passes of the test load truck without any breaks in the panels. The rivets wore and worked loose, but kept the panels secured together. The rivets are not considered a desirable way to connect the panels, but were used as an expedient to test the panels. The M8A1 panels were the only panels tested that

outweighed the Alcoa panel. The Alcoa panel, at 3.5 lb per sq ft, was over the desired weight of 3.0 lb per sq ft by approximately 17 percent. The Alcoa panel sustained the maximum crushing load of 1250 psi with no failure of panel surface, was third best in the rigidity test, and ranked seventh in the buckling test. The panel had the second lowest cost ($3.18 per sq ft) and the cost would probably go down in a large production contract.

Spur-Ecolite Aluminum Sandwich

Fabrication features

56. Two aluminum sandwich designs fabricated by Spur Industries, Inc., Spokane, Wash., were investigated. Both designs contained an aluminum egg-crate type core design fabricated by The Ecolite Corporation, Spokane. The core was fabricated from 6061-T6 aluminum with material thickness of 0.035 in. and cell sizes of 1 in. square and overall thickness of 1 in. The square cells are formed by joining the aluminum strips mechanically, without bonding or welding, using an interference fit between the slots in the cross members. One design tested had aluminum skins bonded top and bottom to the core to form a sandwich structure (Figure 18), and the other design had the skin

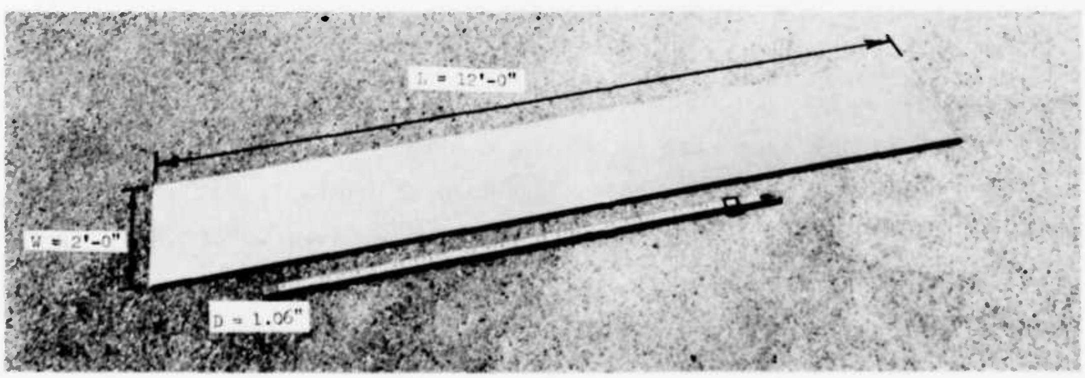


Figure 18. Spur-Ecolite aluminum, 1- by 1-in. core and two-skin sandwich panel

bonded only to one side of the core (Figure 19). The sandwich structure was 2 by 12 ft and 1.06 in. thick and had a weight of 1.8 lb per sq ft. The structure with one skin was the same except it was 1 in.

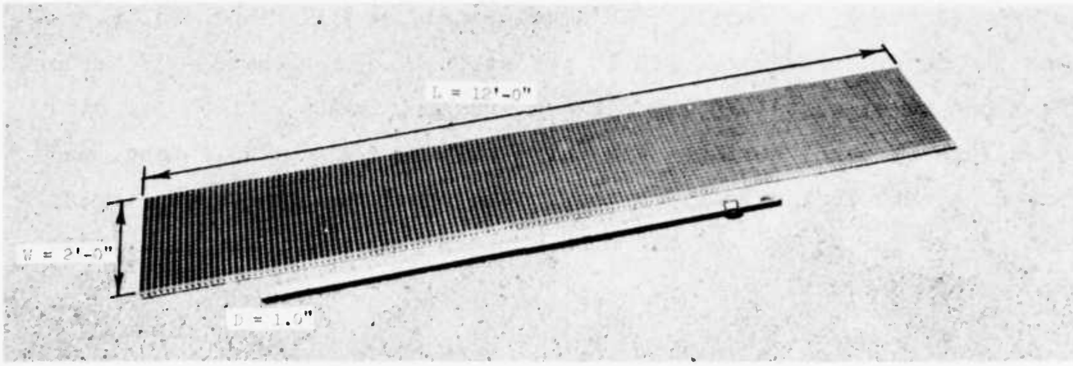


Figure 19. Spur-Ecolite aluminum, 1- by 1-in. core and one-skin panel

thick and had a weight of 1.3 lb per sq ft. Neither of the two designs had side or end connectors as part of the design.

Traffic tests

57. Traffic tests on the two Spur-Ecolite designs were as follows:

a. Item 10 of test section 3, panel with one skin. To evaluate these panels, an extruded H connector was used along the side joints to connect the panels. The panels were placed on the test section with the skin side down and the open or core side exposed. The core was then slightly overfilled with sand which was then leveled with handtools; thus no metal was exposed (Photo 34). After 42 passes of the test vehicle, there was some distortion of the core material. After 142 passes, the square grid pattern on all panels was distorted and the section was rough due to panel distortion, especially in the wheel paths. After 200 passes, the individual ribbons of aluminum that comprised the core were loosening and the mechanical joints of the core were opening and allowing the core to begin to fail (Photo 35). This continued to 300 passes as bond failures were occurring and metal breaks were occurring in the core itself (Photo 36). Disbondment between the core and the bottom skin had allowed the sand in the cells to spill out, thus emptying the core of sand and allowing it to be failed by crushing. Although traffic was allowed to continue beyond 300 passes, for all practical purposes the panels were considered failed at this time as they were no longer satisfactorily supporting the rolling wheel load (Photo 37). Generally, the profile and

cross-section data were very similar throughout the test to that for item 11 as shown in Plate 11.

b. Item 11 of test section 3, sandwich panel with two skins. Again the H connector was used between joints of the panels, with the panels placed on the section as done in item 10 (Photo 38). However, since the panel was a sandwich structure and contained aluminum skins on both top and bottom, the egg-crate core material was not filled with sand (Photo 38). After ten passes of traffic, disbondment of the top skins was occurring in the wheel paths in approximately half of the eight panels. Two panels had creases in the top skins that were 4 to 6 in. long. After 200 passes, the creases and wrinkles in the top skins had increased and were present in all panels. All panels were dished and contained a permanent set of at least 1 in. in the wheel paths (Photo 39). After 300 passes, the surface of the mat was rough to the test vehicle. Skins were disbonded from the core on the top, and the wrinkles in the top skins were more pronounced. All panels had permanent set in excess of 1.25 in. at this time, and item 11 was considered failed (Photo 40). After the H connectors were removed, the top skins were examined and seen to be totally disbonded in the wheel paths (Photo 41). There was also core failure due to breaks and tears in the metal. Profile and cross-section data (Plate 11) indicate that the mat surface generally changed 1 in. during the first 200 passes and that the surface differential was as much as 4 in. at the end of traffic.

58. A verification test was conducted on two Spur-Ecolite panels containing one skin, in which one panel was placed on sand with the skin up (item 21) and the other was placed with the skin down (item 22). The test vehicle was again used and two panels were placed on the sand in parallel lanes with the long axis in the direction of traffic, so that both panels could be trafficked simultaneously and thus easily compared. After 80 passes of the test vehicle, the panel with the skin up had failed. The core had disbonded from the skin, the core was split and broken, and the skin was wrinkled. However, after 80 passes on the panel with the skin down and the core openings filled with sand,

there was no disbondment and no apparent failure. Profile data (Plate 12) indicate that the panel with the skin down (item 22) embedded approximately one-half as much as the panel with the skin up (item 21) at an equal number of passes. Thus, as anticipated in initial studies of the design, the Spur-Ecolite panels with one skin perform better on sand if the skin is placed down and the open-square cells are filled with sand (Photo 42). This arrangement assures that the cells will be filled with sand which provides added strength to the core members.

Laboratory tests

59. Since the Spur-Ecolite panels (both one- and two-skin designs) did not have side or end connectors, and since only a minimum number were available for testing, neither the buckling nor the rigidity tests were conducted. It was felt that the panels as received were not capable of supporting beam or column loading without some type of closure or connector device around the perimeter that would protect the panel edges and contribute to stability. The crushing test was conducted on both the sandwich panel with two skins and the panel with one skin (skin side up). Since they both had the same type of core material, 1-in.-square cells, the resulting compressive strengths were generally the same. The sandwich panel had a crushing strength of 770 psi (Table 3) and the panel with one skin had a strength of 775 psi. These results were the lowest of all panel designs tested with the exception of the Fletcher aluminum panel and the Ecolite cores tested without skins.

Analysis of results

60. The Spur-Ecolite panels with both one and two skins did not perform well in either the traffic or the laboratory investigation. The profile along the wheel path indicates severe distortion due to traffic. Although the panels weighed less than 2.0 lb per sq ft and were the lightest sandwich materials tested, the test results were not impressive compared with other structures investigated. The large cells of the core material give very little contact area for bonding of the skins. Also, unless the core was filled with sand, it could not

adequately support the vehicle loads for prolonged trafficking. Thus, the Spur-Ecolite panel with skin(s) is not recommended for further testing in the present form.

Woodside Formed Aluminum

Fabrication features

61. The panels fabricated by Woodside Engineering Company, East Franklin Park, Ill., were designed by WES personnel in an attempt to develop a relatively simple inexpensive panel (Plate 13). The panel was fabricated from 0.1-in.-thick 6061-T6 aluminum alloy by using a break press method to form the body ribs and connectors. The individual panels are 22.5 in. wide, 12 ft long, and 1.56 in. in overall thickness and have a weight of 2.0 lb per sq ft of placing area (Figure 20). The side connector, which is an integral part of the

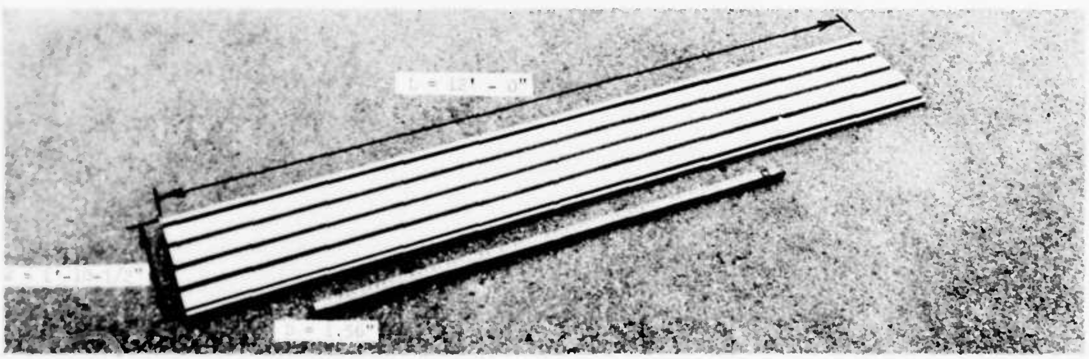


Figure 20. Woodside formed aluminum panel

basic panel, is continuous along the panel length and provides a relatively closed connection to deter water entry into the joint. One person can connect and assemble individual panels, which weigh only 46 lb each. One major drawback to this rather simple design is the rather expensive initial tooling setup which may be required to fabricate a rolled-form panel of this type.

Traffic tests

62. The Woodside formed aluminum panels were item 24 of test section 4. Only six panels were available for traffic testing, making the item 12 by 12 ft. After one panel was placed on the test section,

the next panel was joined by inserting the panel connector perpendicular to the ground in the joint being placed and allowing the panel to rotate toward the ground as the connectors hinged together. No other hardware is required in joining the panels as the connectors are self-contained. Again the test section was loose dry sand and no special compaction effort was made on the sand prior to panel placement (Photo 43).

63. The design of the panel joints allowed sliding of the individual panels relative to one another. This feature would allow individual panel replacement, if desired should a panel fail, without removing a series of panels to get to the failed panel. Although the panels contained some distortion along the length of the connector, apparently from irregularities created during fabrication, they could be slid along the 12-ft length. As traffic progressed, the action of the test vehicle rolling across the item caused some of the loose, dry sand to be blown out from under the panels at the panel ends. Thus, the profile data showed a gradual increase in subsidence of the panels as traffic progressed. However, there was little distortion or permanent set in the individual panels. After 200 passes, no distortion, rutting, or dishing was observed and individual panels could still be slid and removed laterally with respect to one another. Only after 700 passes was any distortion evident. After 2000 passes, the panels were still in excellent condition (Photo 44). As traffic progressed to 3000 passes, there was no sign of connector failure or disengagement. Some minor pumping of the dry sand particles was observed along the joints at the center line; however, the panels were in excellent condition overall and capable of sustaining additional traffic (Photo 45). Profile data (Plate 14) show that the panels embedded or settled uniformly approximately 2 in. during the traffic. The surface was slightly rougher at 3000 passes than at the beginning of traffic.

Laboratory tests

64. The laboratory tests conducted on these aluminum panels gave very good results, especially considering that the weight was only 2.0 lb per sq ft. The panel sustained 4590 lb loading per foot of width

(Table 2) in buckling and 745 lb per foot of width at 4-in. deflection in the rigidity tests (Table 2 and Plate 4), which indicate excellent column and beam properties for a formed panel design. The crushing test with the container corner indicated the panel could sustain 800 psi (Table 3) on a flat metal loading table; however, it is felt that if the same panel were placed on sand and embedded slightly, the load it could support would be higher since the ribs in the panel would have less of a tendency to "unroll" and more contact would be available on the bottom panel surface.

Analysis of results

65. The beam test results of the Woodside panel indicated that this formed aluminum design resulted in lesser deflections at any given load than did the similar design of the Fletcher panel, the Wells and Taber extruded aluminum panels, and the M. C. Gill sandwich panel. For its weight and simplicity of design, this panel, which was 6061-T6 alloy material, gave excellent results. The profiles along the wheel paths showed only a 2-in. change in elevation throughout the test, and this was a uniform change caused by the dry sand being pumped out from the edges of the panels. Since it sustained the 3000 passes of the fully loaded vehicle, it ranks as one of the top materials to be considered for future evaluations. The connectors along the 12-ft side could be easily waterproofed since the as-fabricated mat is designed to prevent water entry up to a certain depth on the mat surface, and low-strength subgrades should not have a tendency to extrude through these joints. The overall test results of the Woodside panel would rank it high, provided the cost of fabrication equipment to provide this simple design can be kept to a minimum.

PART IV: TESTS OF RELATED MATERIALS

Ecolite Aluminum Egg-Crate Core

Fabrication features

66. As a part of the investigation of the Spur-Ecolite sandwich panels, it was also decided to study the open egg-crate core material alone as a surfacing in sand. The core was furnished by Ecolite Corporation in two grid sizes, 1/2- and 1-in. openings, with overall core thicknesses of 1/2 and 1 in., respectively. The core materials, fabricated from 6061-T6 aluminum alloy, were furnished in nominal panel sizes of 2 by 12 ft with the 1/2-in. grid material weighing 0.4 lb per sq ft and the 1-in. grid material weighing 0.8 lb per sq ft (Figures 21 and 22). The grid ribbon material for the 1/2- and 1-in. cores was 0.015 in. and 0.034 in. thick, respectively.

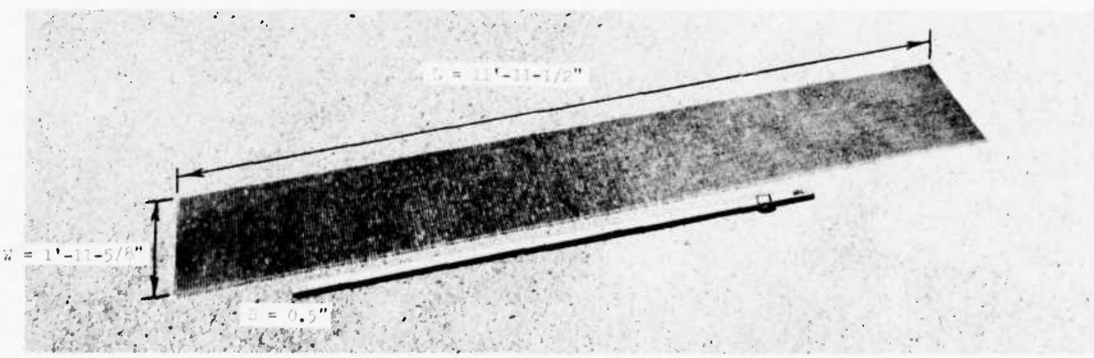


Figure 21. Ecolite 1/2- by 1/2-in. grid core

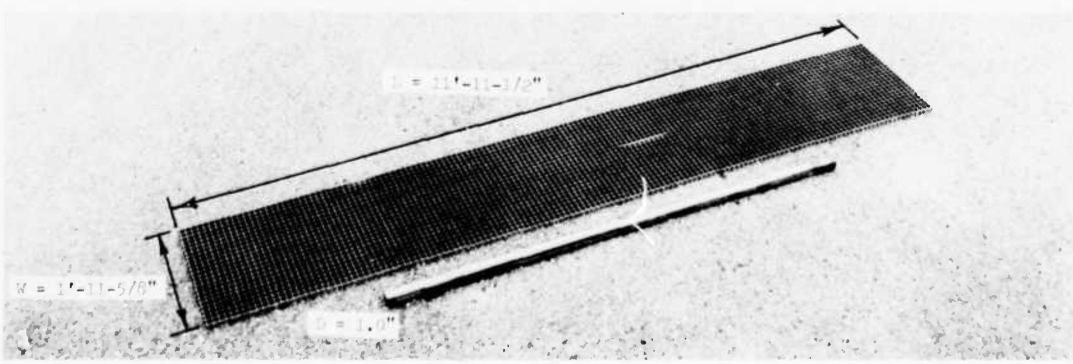


Figure 22. Ecolite 1- by 1-in. grid core

Traffic tests

67. In initial testing of the core, one of the 1-in. cores was placed on the dry sand, filled with sand, and trafficked with 400 passes of the test vehicle (item 9). During the first 200 passes, the core material performed satisfactorily in the wheel paths as the core continued to embed in the sand; however, the untrafficked areas tended to curl up and/or remain higher than adjacent material and cracks and breaks began to occur between these areas (Photo 46). After 300 passes, core crushing occurred as the sand escaped from the cells and the core was torn and flattened (Photo 47). For all practical purposes, the material was considered failed at this time as it would cause a hazard to vehicular traffic tires. The 1-in. grid core was placed on the sand again and the voids were filled with sand; however, the long axis of the core was oriented with the direction of traffic (Photo 48). In this test the test vehicle was allowed to drive up on the core from the sand; however, the drive wheels of the truck, in attempting to pull out of the immobilizing sand, caused severe breakage of the unprotected open-grid core material (Photo 49). Thus, the single thickness of the unsupported 1-in. core alone on the sand did not prove to be an adequate supporting material for the vehicle as loaded; hence, the 1/2-in. grid core in a single layer was not tested.

68. In an effort to determine the benefits of the open-grid designs in thicker sections, both the 1/2- and the 1-in. grids were placed in double layers (items 12 and 13, respectively). In each test the two layers were filled with sand and separated by approximately 1/2 in. of sand with the top layer overfilled with 1/2 to 3/4 in. of sand. The 1/2-in. grid material in two layers sustained 200 passes of traffic before it was considered failed due to rutting. The 1-in. grid material performed much better in that it sustained 1000 passes before failure due to rutting. Profile data (Plate 15) indicate that the 1/2-in. grid core embedded 2 to 3 in. more than the 1-in. grid core at a comparable number of passes of the test vehicle. In both tests, only four panels were involved and the test was conducted in an attempt to gain additional information on ways to improve and to gain new data on

the open-grid concept. Generally, the panels performed well in the wheel paths whereas the untrafficked areas tended to curl up, lose sand from the grids, and then become crushed and flattened if and when the load wheels wandered on these edges. However, there was an overall change in elevation of approximately 8 in. in both materials as the core was embedded into the sand. Thus, there is potential merit in a thicker section if refinements can be made to keep the grid material in a flat plane.

Laboratory tests

69. Since the Ecolite material was not a panel and was only evaluated as a raw core in these tests, the only laboratory tests conducted were the crushing tests. As expected, the results of the crushing tests of the 1-in. grid material were similar to results obtained on the 1-in. grid material with skins, since the skins only provided a bearing surface for the loading head. Thus, the 1-in. grid attained 725 psi in crushing but the 1/2-in. grid sustained only 420 psi (Table 3). However, the metal thickness of the grid material in the 1/2-in. grid was only 0.015 in., whereas in the 1-in. grid material it was 0.034 in.

Analysis of results

70. The results of the investigations on the raw core materials without skins indicate that for the vehicle loadings it was subjected to, the materials proved to be the weakest items tested. To achieve any traffic support at all required the placement of the material in two layers; however, even this did not give satisfactory results. These materials also resulted in the lowest laboratory test results of the materials tested. Some credit should be given to the cost of the materials, which was minimal. By increasing the basic component thicknesses (and cost), better results could possibly be attained.

Hexcel Paper Honeycomb Core

Fabrication features

71. The Hexcel paper honeycomb material was fabricated in several cell sizes and thicknesses. The honeycomb cells were

hexagonal and formed from bonded unimpregnated Kraft paper. The honeycomb was provided in the flat and unexpanded condition and had to be pulled open by hand and either anchored or the cells filled with sand to keep it in its expanded shape. The Hexcel cores used in this investigation were small samples of the material and were being used merely in an attempt to learn the combinations of cell sizes and thicknesses that would result in the best performance in sand.

Traffic tests

72. There were several available sizes of the paper honeycomb to evaluate, and in initial tests, the large cell materials were evaluated first. Thus, a 1-1/2-in. and a 3-in. cell honeycomb were subjected to traffic (items 14 and 15, respectively). Both materials were 2 in. in thickness and placed on dry sand and trafficked with the test vehicle. The materials tested were approximately 3 by 12 ft after expansion. The test vehicle made only three passes on these two items and then became immobilized due to tearing and complete failure of the cores. The rutting in the sand and failed core material was as much as 12 in. The cores appeared to be contributing very little to the strengthening of the sand. Profile data (Plate 16) indicate that the material was embedded over 6 in. in several places.

73. Since the single layers of the 1-1/2- and 3-in. cell honeycomb did not contribute to the performance of the test vehicle in dry sand, it was decided to use two layers of the material. Thus, the double layers of paper honeycomb increased the thicknesses to 4 in. for both of the honeycomb samples. In item 16 (north portion of test section) the 1-1/2-in. honeycomb cells were placed and the 3-in. honeycomb cells were placed on item 17 (south portion of test section). All cells were again filled with sand after expanding and in this test, the layers were separated by approximately 1/2 in. of sand. Again, after three passes of the vehicle, the core material was torn rather severely in the top layer, and rutting was occurring (Photos 50 and 51). However, the test vehicle could still maneuver across the section, but with difficulty (Photo 52). After four passes of the test vehicle on the double-layer honeycomb, the section was considered failed as neither

item was capable of supporting the test vehicle, and the test was stopped. Profile data (Plate 16) indicate that the surface changed 4 to 5 in. in both items 16 and 17. From these investigations, it was shown that the 1-1/2- and 3-in. celled core was not satisfactory for the 40,000-lb test vehicle in dry sand.

74. The next investigation in this series was to again use two layers of honeycomb, but use 1-1/2- (item 18, north portion of test section) and 3/4-in. (item 19, south portion of test section) cells and a lighter truck. A 1/2-ton pickup truck was chosen as the initial vehicle which without some type of surfacing could not maneuver across the sand. Again the two layers of honeycomb were placed on the dry sand, the cells were filled with sand, and a 1/2-in. layer of dry sand was placed between the two layers of honeycomb and on top of the top layer. The lightweight truck (empty, 3700 lb) was trafficked across the section for 50 passes, and no damage was sustained by the honeycomb (Photo 53) on either of the two honeycomb samples. At this time, the weight of the truck was increased to 4700 lb by adding a 1000-lb payload. Traffic was then resumed for 150 additional passes, making a total of 200 passes of the pickup truck. The only change noticeable was a change of approximately 1 in. in elevation of the profile along the center line (Plate 16).

75. Next a 1-1/2-ton, 6-wheel (two steering wheels and dual drive wheels), flatbed truck was used. The total weight was 9885 lb. This truck was used for 50 passes, for a total of 250 passes of mixed vehicular traffic. The 1-1/2-in. cell honeycomb seemed to be moving and deflecting more while the truck was moving over it than did the 3/4-in. cell material. An additional 5000-lb payload was added, increasing the total gross weight to 14,885 lb, and 50 more passes were run. At this time, the 1-1/2-in. material was showing a lower profile and some of the honeycomb cells were distorting and beginning to tear along the edges. At a total of 372 passes, the paper core material on the 1-1/2-in. cell material began tearing between the dual wheels and severe rutting began to occur. Truck traffic was continued through 400 passes on both items 18 and 19. Profile data (Plate 16) show

that at 400 passes item 18 was embedded 6 in. whereas item 19 was embedded less than 3 in.

76. At this point (400 total passes), the 1-1/2-in. honeycomb material was considered failed due to disintegration of the material, and it was no longer considered suitable for traffic (Photo 54). In comparison, the 3/4-in. honeycomb was still performing satisfactorily and in excellent condition (Photo 55). Thus, matting was placed over the failed material and traffic was continued on the 3/4-in. material. After 500 total passes, there was some indication of failure along glue lines in the 3/4-in. cells in the top layer, although it was not critical at this time. However, after 1000 passes, four glue lines had failed as indicated by separations of the ribbons. The rut depth between the outside edges of the honeycomb and the center was as much as 4-1/2 in. However, this was due primarily to the curl up of the edges in the nontraffic areas. After a total of 2000 passes of the mixed traffic of the 1/2-ton pickup and the 1-1/2-ton truck, the rut depth had increased to approximately 9 in. on the 3/4-in. cell material, and both layers were turning up along the outside edges. The previously failed three or four bond lines tended to relieve some of the stresses in the honeycomb and these areas were still performing satisfactorily. Except for the outside edges which had not been trafficked and were curling up and losing the sand in the voids, the core was performing satisfactorily (Photo 56). Trafficking was discontinued at this time with the 1-1/2-ton truck. Profile data (Plate 16) indicate that the honeycomb had continued to embed in the sand to a maximum of 6-3/4 in. or for an average of approximately 5 in. For information purposes, eight additional passes of the original 5-ton truck with a 40,000-lb payload were applied to the section, and the honeycomb showed no change or additional distress due to this loading. Additional traffic was not applied as examination of both layers of the honeycomb was desired. The examination revealed that the bottom layer was contoured to the top and that breaks were similar in both layers but to a lesser degree in the bottom layer.

Laboratory tests

77. Due to the nature of the design and the type of material, no laboratory tests were conducted on the Hexcel paper honeycomb material. The material attains its performance strength when it is expanded by hand and the resulting voids are filled with sand. Thus, no laboratory evaluations were made on the basic materials.

Analysis of results

78. The purpose of conducting the numerous traffic tests on the variations and combinations of cell sizes and core thicknesses was to determine the optimum sizes to give the best performance. Although the tests were restricted to 2-in.-thick samples, the samples were placed in double layers in some tests to evaluate the possible benefits of thicker sections. The 3/4-in. material in two 2-in. layers gave the best performance of all of the paper honeycomb combinations tested. Although it appears that the greater the depth of the material the larger the cell size that can be tolerated, this could not be evaluated on depths greater than 4 in. overall. Future evaluations should be directed to single layers of materials in thicknesses up to 6 in. with a variation in cell size. It was concluded that the materials tested in this study have potential for use in sand for lightweight vehicular traffic.

T16 and WX18 Membranes

79. In an attempt to compare some of the benefits of the mat/panel materials being tested, it was decided to have the 5-ton test vehicle traverse the dry sand test section surfaced with membrane surfacing and with no surfacing. When the test vehicle attempted to make a pass across the bare section, it quickly became immobilized and had to be towed out of the sand. The dry sand "flowed" around and between the rear drive wheels as the tires sank into the sand (Photo 57). The undercarriage of the test vehicle was soon touching the sand after only a short distance into the section and thus the test vehicle became immobilized (Photo 58).

80. The T16 membrane, which is a single-ply, neoprene-coated nylon, was placed on the sand test section to determine if it would support movement of the test vehicle through the sand (Photo 59). The sand had been releveled and the section was relatively smooth. During the first pass of the test vehicle, 4- to 5-in. ruts occurred along the wheel paths, and the membrane was pulled into the ruts and became very wrinkled (Photo 60). As traffic progressed, the ruts became deeper and additional membrane was being pulled into these ruts. After 7 passes of the test vehicle, the ruts were as much as 11-1/2 in. deep and the differential of the test vehicle began to drag the membrane. Thus, traffic was not continued on the T16 membrane beyond seven passes as tearing and damage to the membrane would have occurred. Profile data (Plate 17) show that the membrane surface was forced down an average of approximately 5 in.

81. A heavier membrane, the WX18, a 4-ply, neoprene-coated nylon, was placed on the sand test section after the test section had been leveled. Again as the test vehicle made passes across the section, the sand rutted and the membrane was pulled into the ruts and accumulated in the ruts as traffic progressed. After eight passes, the test vehicle could still maneuver across the section although most of the membrane had been pulled toward the ruts from the edges (Photo 61). The ruts measured approximately 9-1/2 in. deep and the wrinkles were quite numerous. Since the membrane tended to accumulate in the bottom of the ruts, the several layers of thickness of membrane prevented the tires from sinking deeper into the sand, and the test vehicle could still maneuver across the sand but with some difficulty (Photo 62). Traffic was discontinued, although the test vehicle was not dragging after eight passes as it did with the T16 membrane. Due to their bulk and inability to increase the strength of the subgrade, the membranes would not be considered a satisfactory surfacing material.

PART V: COMPARISONS, CONCLUSIONS, AND RECOMMENDATIONS

Comparisons and Conclusions

82. Without specific criteria to rate or compare the mat/panels, they were compared or rated against each other. Even though the project was low funded, numerous materials and fabrication methods were investigated. From the test data and best engineering experience, the comparison/rating of the mat/panels is summarized as follows:

a. Eight of the eleven general-purpose mat/panels tested (Wells, Woodside, Kaiser 2.5 and 3.0 lb, Taber, Alcoa, Fletcher, and M8A1) sustained the total traffic of 3000 passes. Of these, the Taber had internal failures at 677 passes and became progressively rougher with additional traffic. The Fletcher panel developed a break at 2500 passes and became progressively rougher with additional traffic; the ends curled up and the breaks were a tire hazard by 3000 passes. The Gill mat sustained 2000 passes, and the Spur-Ecolite (one and two skins) sustained only 300 passes.

b. Of the eight mat/panels that sustained the 3000 traffic passes, five (Woodside, Kaiser 2.5 and 3.0 lb, Taber, and Fletcher) met the desired maximum weight of 3.0 lb per sq ft. The Wells panels (3.2 lb per sq ft) were only 6 percent and the Alcoa panels (3.5 lb per sq ft) 17 percent heavier than the desired weight. The M8A1 (7.5 lb per sq ft) was 2.5 times heavier than the desired weight.

c. Four of the panels (Wells, Taber, Alcoa, and M. C. Gill) sustained the maximum crush test of 1250 psi. The Kaiser 2.5-lb panel sustained 87 percent and the Woodside sustained 64 percent of this load.

d. In the rigidity test of the panels that withstood the 3000 passes of traffic, the values sustained ranged from 300 to 760 lb per foot of width.

e. The range of values in the column test was between 3560 and 7880 lb per foot of width for those panels that sustained the

maximum traffic of 3000 passes. Generally, the thicker panels sustained the highest loads.

f. The 3.0- and 2.5-lb Kaiser sandwich construction panels generally produced similar test results. In this fabrication method, the less materials required for a panel generally is the most economical; therefore, the lighter panels are preferred for further testing.

g. Cost comparisons for experimental quantities are deceptive and should be avoided. Cost quotes from fabricators for production quantities (multimillion square feet) indicate that the extruded, formed, or sandwich mat would cost approximately $3.00 per sq ft on the 1976 market.

83. From the related studies of other materials for use in traversing sands, the following results were obtained:

a. The T16 and WX18 membranes supported the test vehicle for 7 to 8 passes but the edges were pulled into the ruts by the drive wheels.

b. The 1- by 1-in. Ecolite core in a single layer filled with sand supported 300 passes of the test vehicle. In a double layer filled with sand, the core supported 1000 passes of the test vehicle.

c. The 1/2- by 1/2-in. Ecolite core in double layers filled with sand supported the test vehicle for 200 passes.

d. The Hexcel 2-in.-thick paper honeycomb core with 1-1/2- and 3-in. cells filled with sand in single layers supported the test vehicle for three passes. In double layers, the same cores filled with sand supported the test vehicle for only four passes.

e. The Hexcel 2-in.-thick paper honeycomb core with 1-1/2-in. cells filled with sand in double layers supported the mixed vehicular traffic of 50 passes of a 3700-lb pickup truck plus 150 passes of a 4700-lb pickup truck plus 50 passes of a 1-1/2-ton (9885 lb) truck plus 150 passes of a 1-1/2-ton (14,885 lb) truck for a total of 400 passes. The Hexcel 2-in.-thick paper honeycomb core with 3/4-in. cells filled with sand in double layers supported the above-mentioned 400 passes of mixed vehicular traffic plus 1600 additional passes of the 14,885-lb truck and 8 passes of the M54 test vehicle (40,000 lb) for a total of 2008 passes.

Recommendations

84. Based on the results obtained in this investigation, the following recommendations are believed warranted:

a. Kaiser aluminum 2.5-lb honeycomb core panels, Wells extruded aluminum panels, and Woodside formed aluminum panels should be further evaluated as general-purpose mat/panel materials.

b. Alcoa extruded aluminum panels, Taber extruded aluminum panels, and the Sargent-Fletcher formed aluminum panels are marginal mat/panels and should not be further evaluated as a general-purpose mat/panel.

c. M8A1 mat should be considered as a general-purpose mat/panel only because of its availability and low cost.

d. Kaiser 3.0-lb panels should not be considered for further testing as a general-purpose mat as the companion Kaiser 2.5-lb lighter panel appears to be promising.

e. No further evaluation should be conducted on the M. C. Gill and Spur-Ecolite sandwich panels for use as a general-purpose mat/panel in their present configurations.

f. Further evaluations should be made on cell sizes and core thicknesses with the Hexcel and Ecolite core materials for over-the-beach usage and/or for soil strengthening for vehicle traffic.

g. No further testing should be conducted on T16 or WX18 membrane for over-the-beach usage or for soil strengthening for vehicle traffic.

85. The following criteria will be used as a guideline in further testing and developing a general-purpose mat/panel:

a. The panels must be capable of sustaining 3000 passes of the M54 truck with gross weight of 40,000 lb using tires inflated to 70 psi on a loose dry sandy soil.

b. Individual mats must be of such size, shape, and weight as to be handled by two men (desirable maximum weight, 100 lb; essential maximum weight, 120 lb; maximum dimensions, 12 by 4 ft. The 12-ft

length and 3.0-lb-per-sq-ft weight are maximums.) Half-panels may be required.

c. Panels must be provided with connectors on all edges. Ancillaries must be provided to make 90-deg corner connectors for vertical construction.

d. Panels must be coated with an antiskid to provide a coefficient of friction between 0.4 and 0.8 when wet or dry.

e. Panels must withstand a crushing load of 1250 psi, as determined when using a container corner.

f. Mats must support 400 lb per foot of width at a maximum deflection of 4 in. when tested as a beam using a 10-ft span and one-third point loading.

g. Mats must support 4000 lb per foot of width at a maximum midpoint deflection of 4 in. when tested as a 12-ft column.

h. Multimillion square feet production cost should be approximately $3.00 per sq ft.

Table 1

SUMMARY OF CBR, WATER CONTENT, AND DRY DENSITY DATA

Test Section No.	Number of Passes	Location	Depth in.	Water Content %	Dry Density pcf	CBR
1	0	0+15 (Center line)	0 6	3.7 5.4	93.8 97.4	1.8 3.6
1	0	0+60 (Center line)	0 6	1.6 5.3	94.4 98.7	1.5 3.7
1	3000	0+12 (North wheel path)	0 6	0.7 4.3	101.8 104.8	12.0 16.7
1	3000	0+50.5 (South wheel path)	0 6	0.2 1.3	103.1 104.1	1.5 3.4
2	0	0+20 (Center line)	0 6	3.2 2.5	91.4 99.5	1.1 1.2
2	0	0+46.5 (Center line)	0 6	2.2 2.5	91.1 95.2	1.1 2.5
2	3000	0+29 (North wheel path)	0 6	1.3 3.7	101.9 100.9	8.7 15.3
2	3000	0+45 (South wheel path)	0 6	1.1 5.5	102.7 101.6	13.7 14.7
2	3000	0+45 (North wheel path)	0 6	0.9 5.3	99.8 101.3	13.7 14.0
2	3000	0+68 (South wheel path)	0 6	1.6 4.8	100.7 104.0	2.8 14.3
3	0	0+55 (Center line)	0 6	4.4 13.6	92.6 98.2	1.2 2.4
3	0	0+65 (Center line)	0 6	8.6 15.5	92.9 99.6	1.0 2.3
3	400	0+55 (South wheel path)	0 6	3.5 9.1	102.9 103.3	9.3 6.3
3	400	0+68 (North wheel path)	0 6	4.1 10.8	101.9 101.9	6.2 6.7
4	3000	0+54 (North wheel path)	0 6	0.1 0.7	100.1 100.4	1.5 11.0

Table 2

GENERAL-PURPOSE MAT/PANEL DATA COMPARISONS

Item Description	Size L" x W" x D"	Weight, lb Panel	Weight, lb Sq ft	Cost $/Sq ft	Passes	Buckling Lb/ft Width	Rigidity Lb/ft Width	Crushing psi
Extruded aluminum 6105-T6 Wells Aluminum, North Liberty, IN	144x9.64x0.89	28.5	3.2	6.45	3000+	3,560	300	1250+
Extruded aluminum 6063-T5 Taber Metals, Russellville, AR	144x24x1	66	2.8	6.56	3000	3,920	440	1250+
Extruded aluminum 6061-T6 Alcoa, Pittsburgh, PA	144x7.125x1.25	24.6	3.5	3.18	3000	3,830	690	1250+
Formed aluminum 6061-T4 Sargent-Fletcher Co., El Monte, CA	144x22x1.5	43.3	2.1	7.10	3000	4,200	390	233
Formed aluminum 6061-T6 Woodside Engrg Co., Franklin Park, IL	144x22.5x1.56	46	2.0	14.04	3000+	4,590	745	800
Aluminum honeycomb sandwich, 6.1 density, Kaiser-Oakland & Hexcel-Dublin, CA	96.25x48.25x1.46	71.5	2.2	9.76	3000+	5,990	400	1090
Aluminum honeycomb sandwich, 6.9 density, Kaiser-Oakland & Hexcel-Dublin, CA	96.25x48.25x1.49	83	2.6	9.76	3000+	7,880	500	1125
Balsa wood aluminum skin sandwich M. C. Gill Corp., El Monte, CA	144.125x48.125x1.09	93	1.9	4.96	2000	2,834	245	1250+

(Continued)

Table 2 (Concluded)

Item Description	Size L" x W" x D"	Weight, lb Panel	Weight, lb Sq ft	Cost $/Sq ft	Passes	Buckling Lb/ft Width	Rigidity Lb/ft Width	Crushing psi
M8A1 rolled steel landing mat Depot Storage Item	141.75x19.5x1.125	144	7.5	1.06	3000+	5,310	760	1063
Aluminum sandwich with 1-in.-sq. egg-crate core, Spur Industries (Ecolite Corp.), Spokane, WA	144x24x1.06	42.5	1.8	4.79	300	--	--	770
Aluminum skin on 1-in.-sq cell egg-crate core, Spur Industries (Ecolite Corp.), Spokane, WA	144x24x1.0	31.5	1.3	3.59	300	--	--	775
Aluminum egg-crate core (1-in. cells), Spur Industries (Ecolite Corp.), Spokane, WA	143.5x23.625x1.0	20	0.8	1.54	1000 (2 layers)	--	---	725
Aluminum egg-crate core (1/2-in. cells), Spur Industries (Ecolite Corp.), Spokane, WA	143.5x23.625x0.50	9.5	0.4	0.94	200 (2 layers)	--	--	420

(Page 2 of 2)

Table 3

CONTAINER CORNER CRUSHING TEST

Panel	lb	psi	Remarks
Alcoa	50,000	1250+	No failure or indentation
M. C. Gill	50,000	1250+	Very slight indentation
Wells	50,000	1250+	No failure or indentation
Taber	50,000	1250+	Depression 3/16 in. under head
Kaiser (3.0 lb)	45,000	1125	Depressed 1/4 in.; 6- and 4-in. skin tears at edge of head
Kaiser (2.5 lb)	43,600	1090	Depressed 1/4 in.; 3-1/2-in. skin tear at interior edge of head
M8A1	42,500	1063	Panel deformed
Woodside	32,000	800	Panel deformed
Spur-Ecolite, 1- by 1-in. core (1 skin)	31,100	775	Panel deformed
Spur-Ecolite, 1- by 1-in. core (2 skins)	30,700	770	Panel deformed
Ecolite core, 1- by 1-in. grid	29,000	725	Panel deformed
Ecolite core, 1/2- by 1/2-in. grid	16,950	420	Panel deformed
Fletcher	9,300	233	Panel deformed

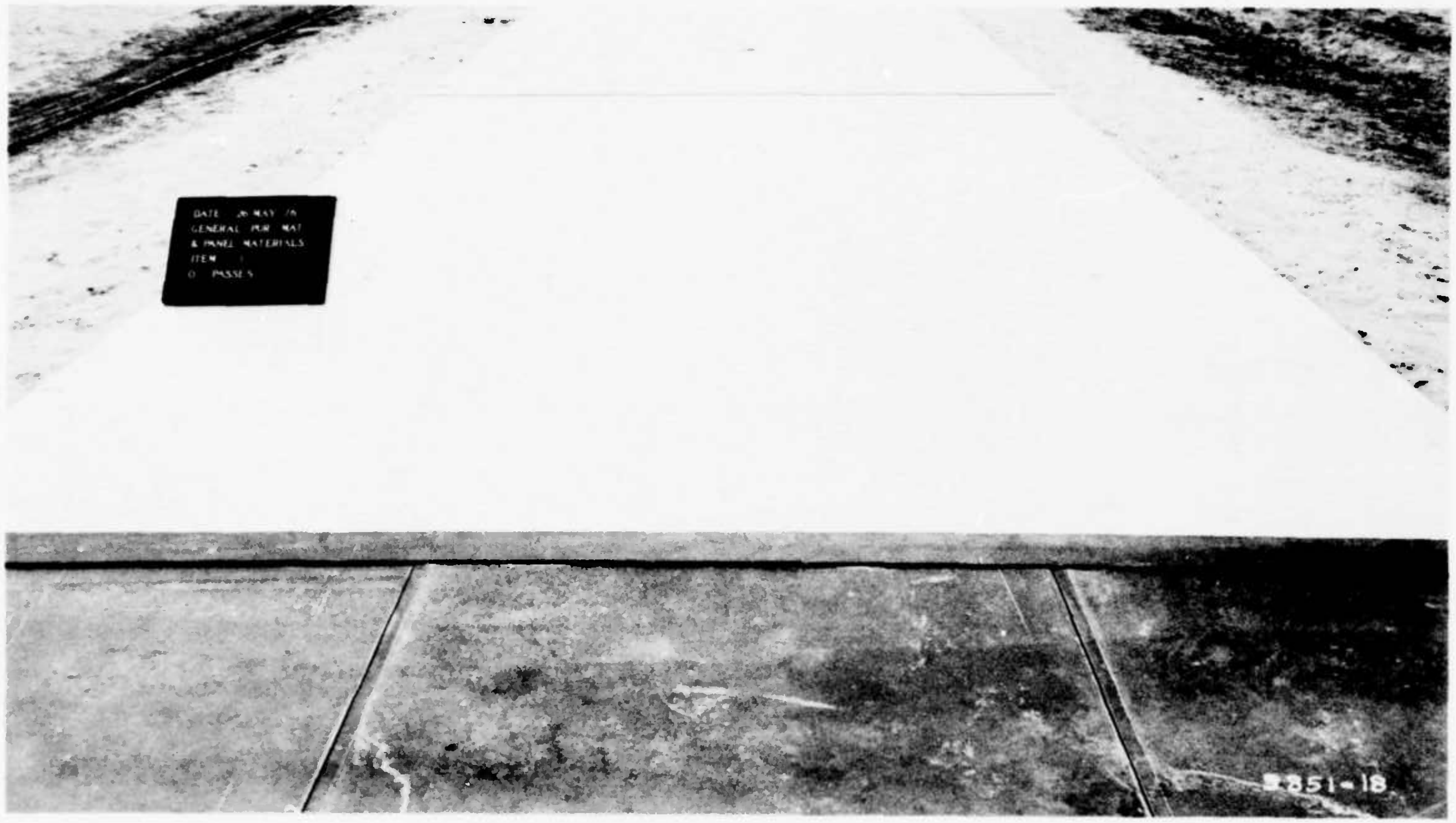


Photo 1. Item 1, test section 1; Wells extruded aluminum prior to traffic

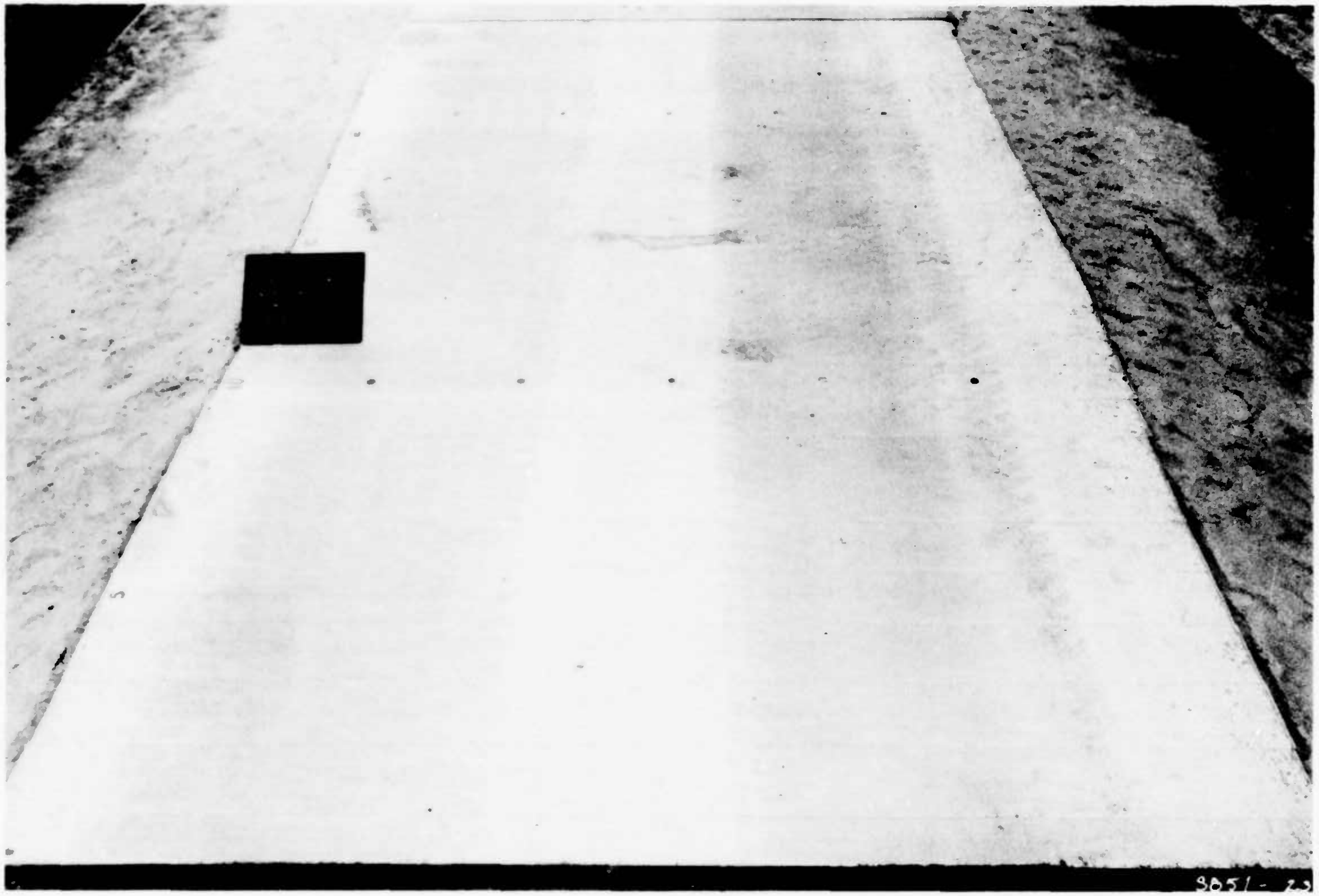


Photo 2. Wells extruded aluminum after 200 passes

Photo 3. Wells extruded aluminum after 2000 passes

Photo 4. Wells extruded aluminum after 3000 passes

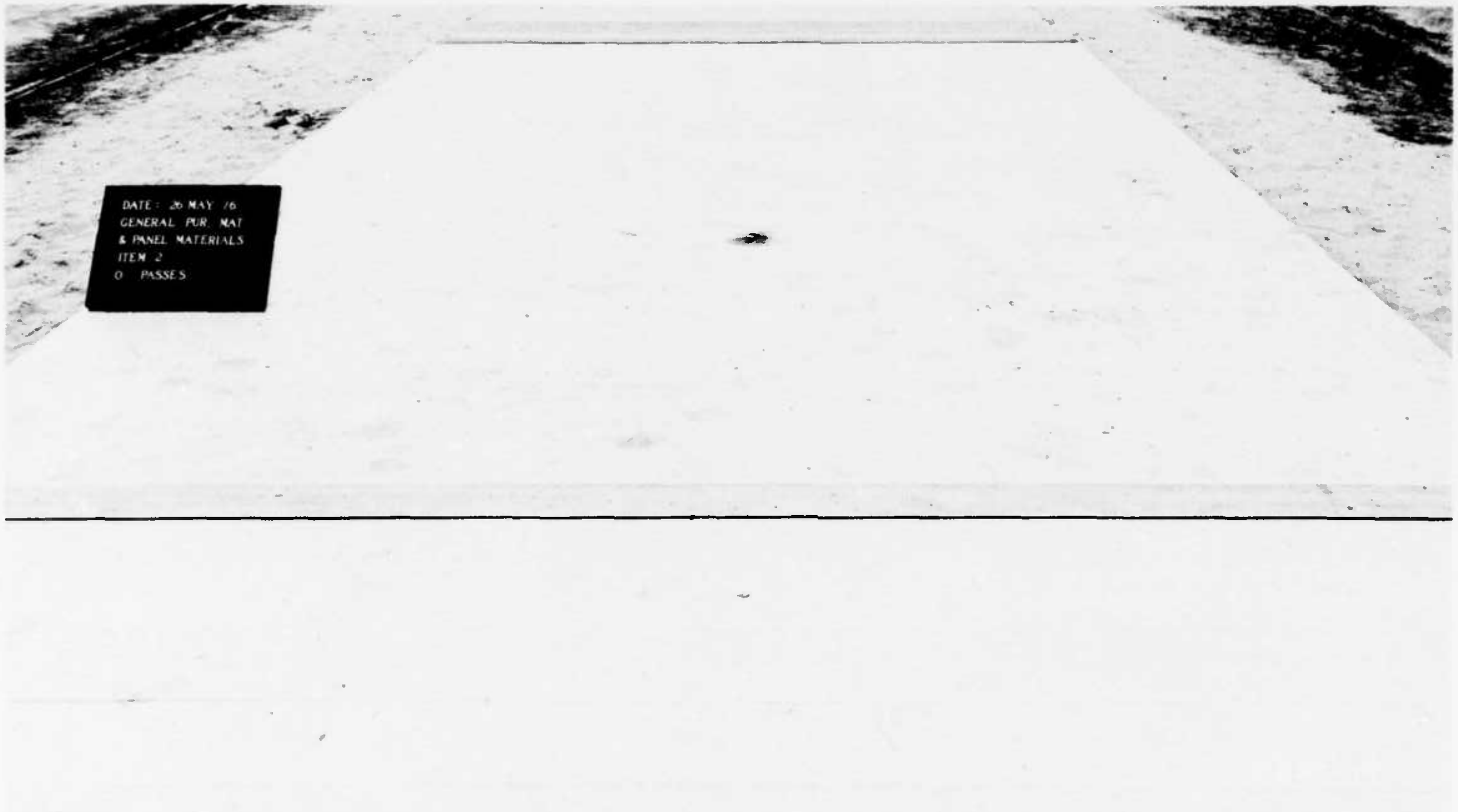


Photo 5. Item 2, test section 1; Taber extruded aluminum prior to traffic

Photo 6. Taber extruded aluminum after 200 passes

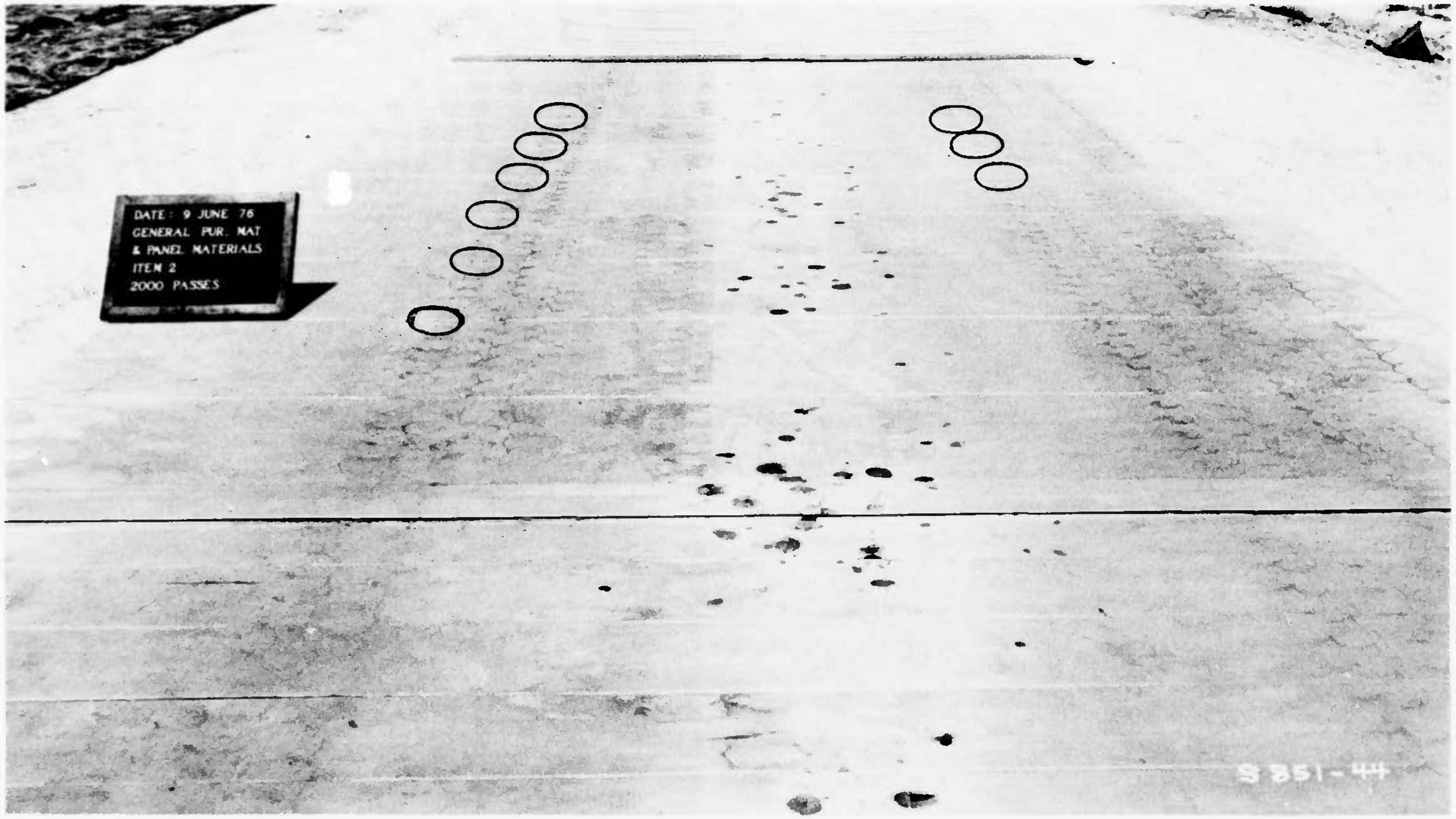


Photo 7. Taber extruded aluminum after 2000 passes
NOTE: Circled where top skin separated

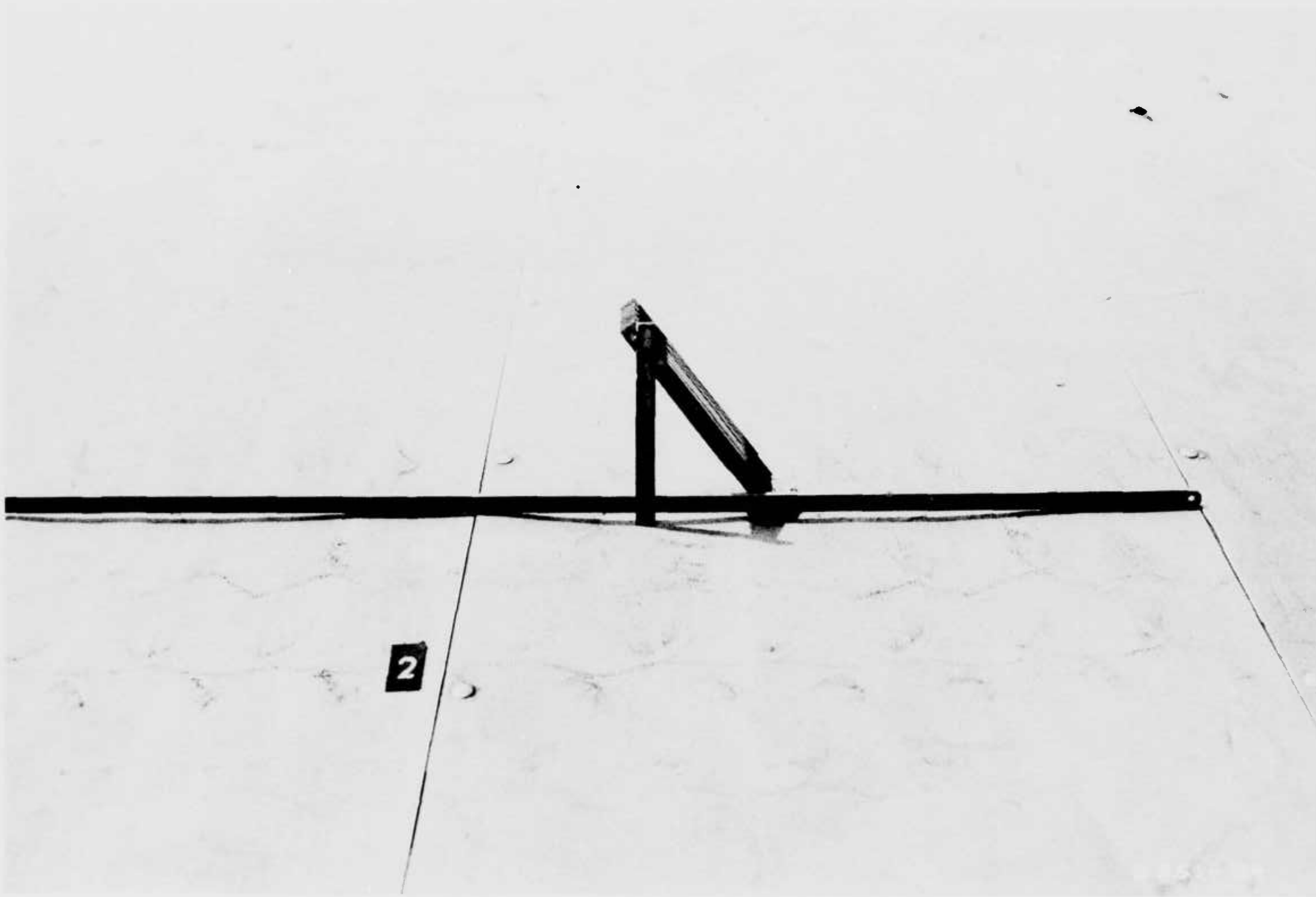


Photo 8. Typical transverse dishing of Taber panels after 2000 passes

Photo 9. Taber extruded aluminum after 3000 passes

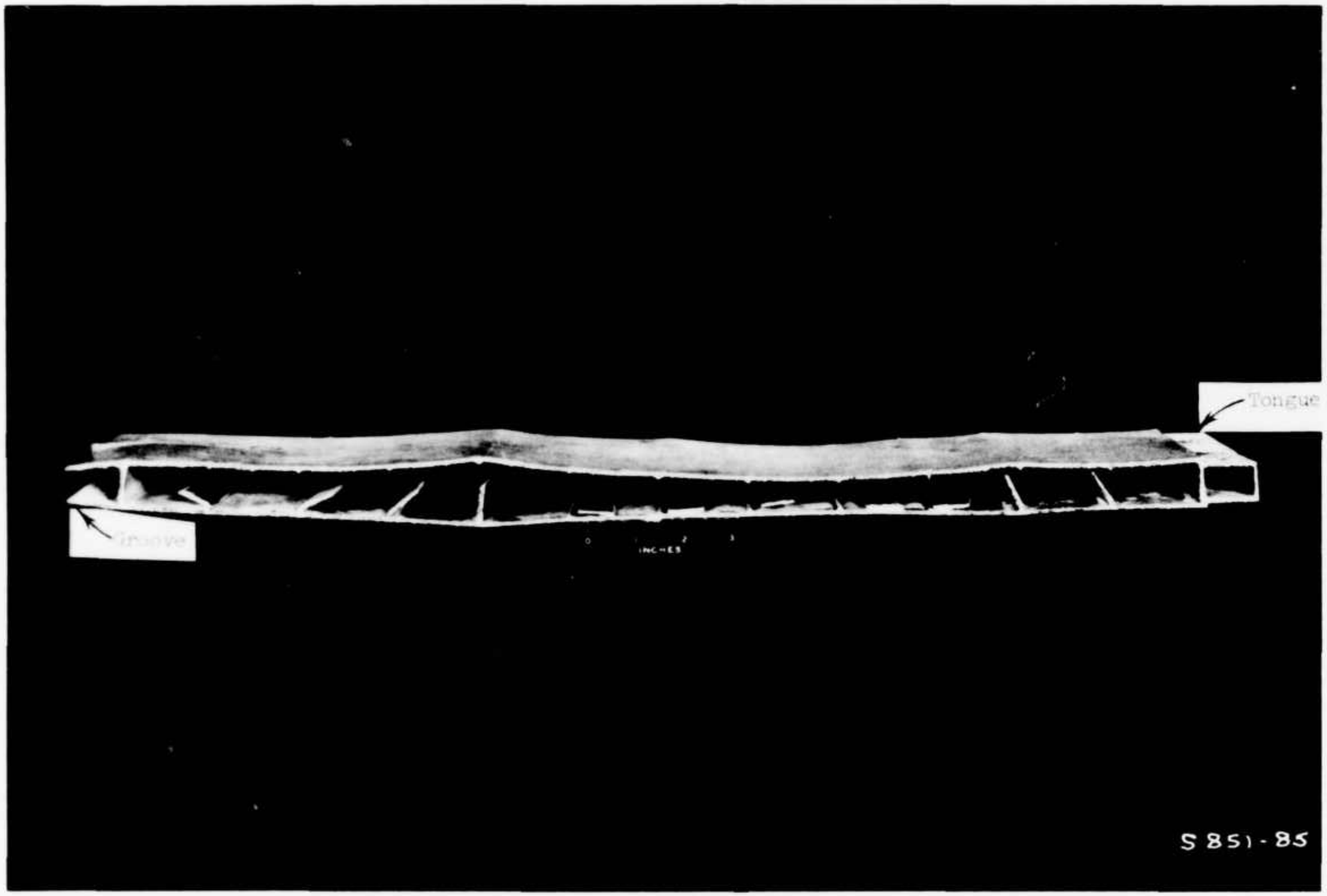


Photo 10. Cross section of Taber panel 33 after 3000 passes

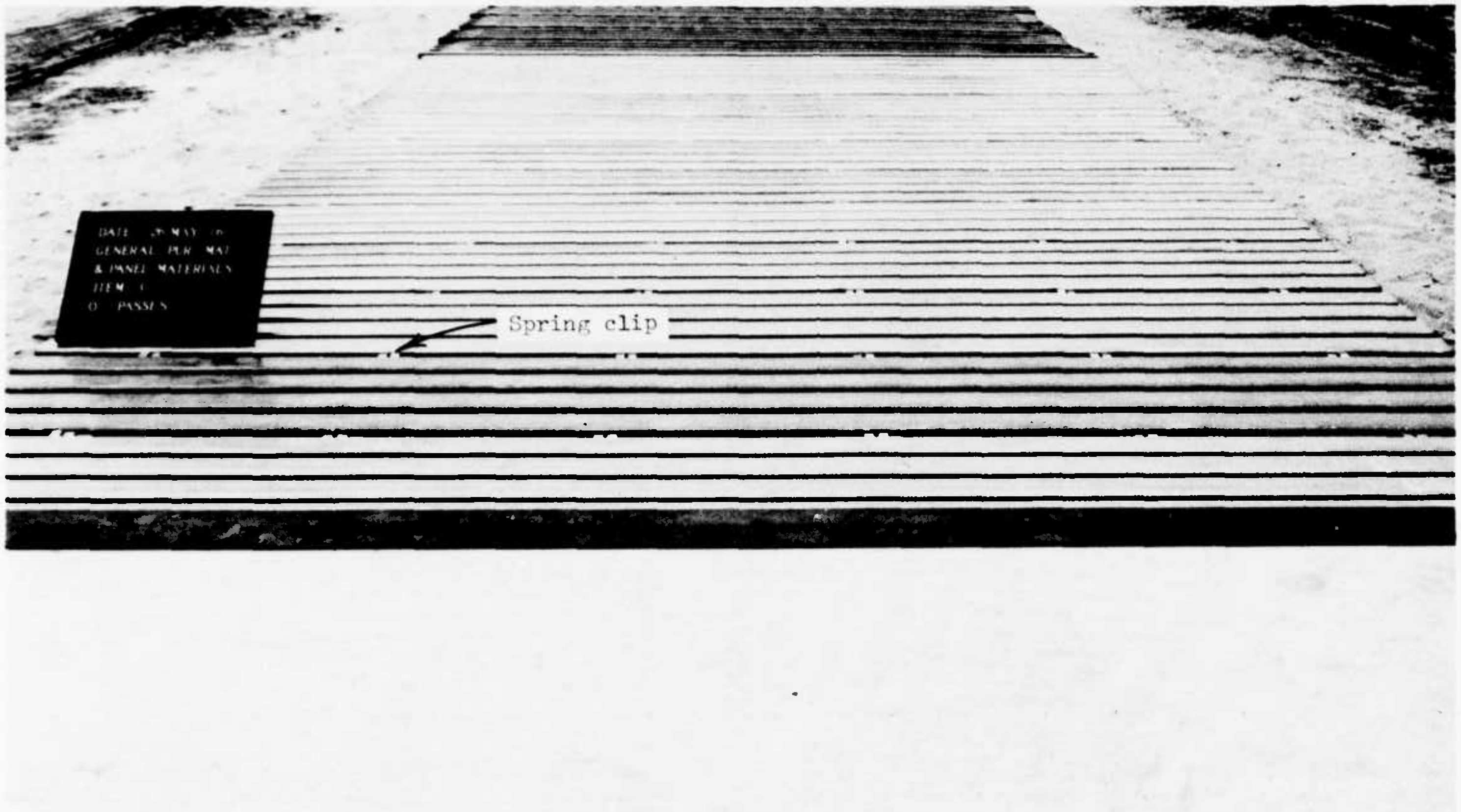


Photo 11. Item 3, test section 1; Fletcher formed aluminum prior to traffic

Photo 12. Fletcher formed aluminum after 200 passes

Photo 13. South edge of Fletcher panels after 200 passes

Photo 14. South edge of Fletcher panels after 1000 passes

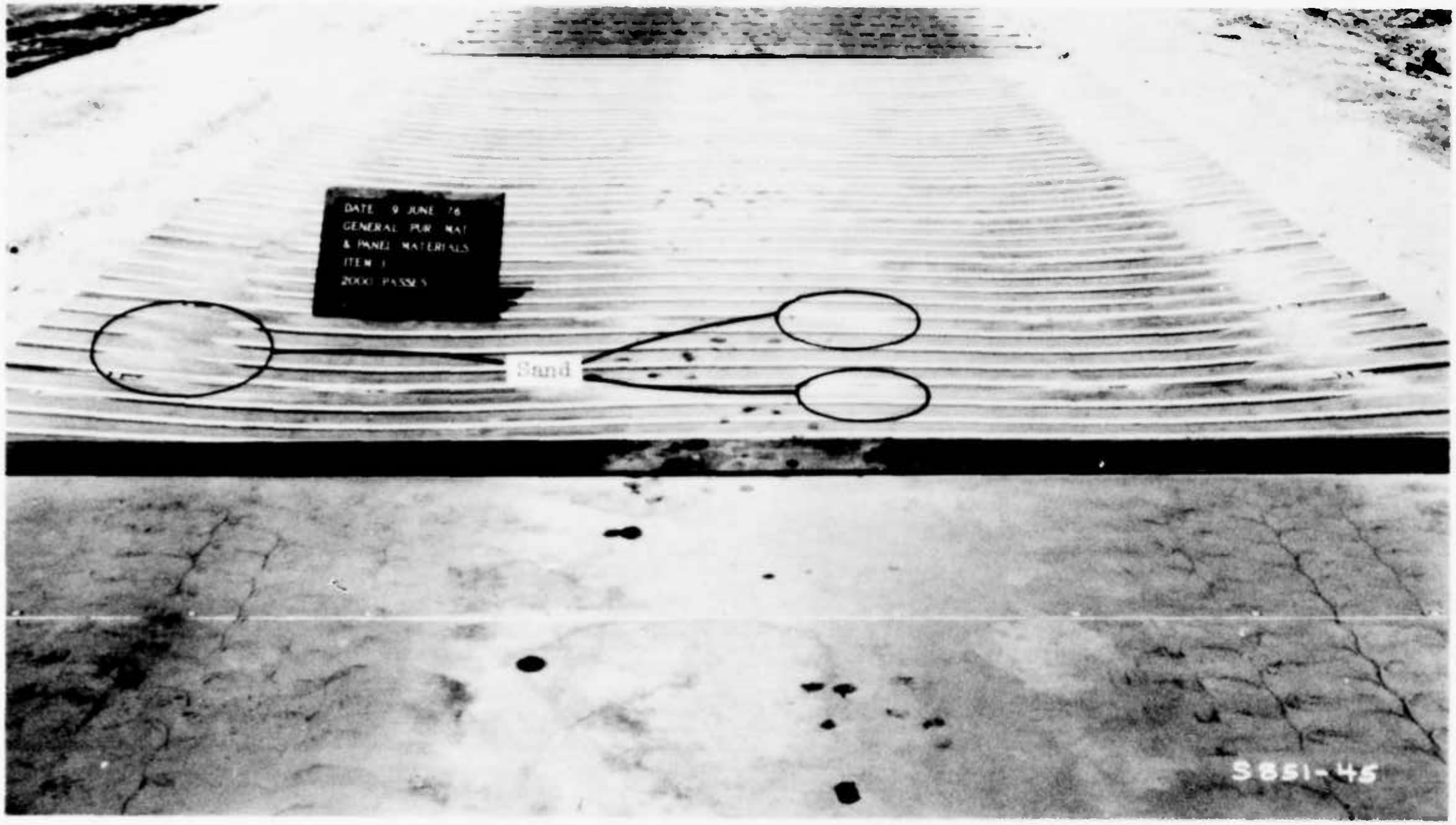


Photo 15. Fletcher formed panels after 2000 passes (note sand on panels)

Photo 16. Typical Fletcher panel joint after 2000 passes

Photo 17. Fletcher formed panels after 3000 passes

Photo 18. South edge of Fletcher panels after 3000 passes

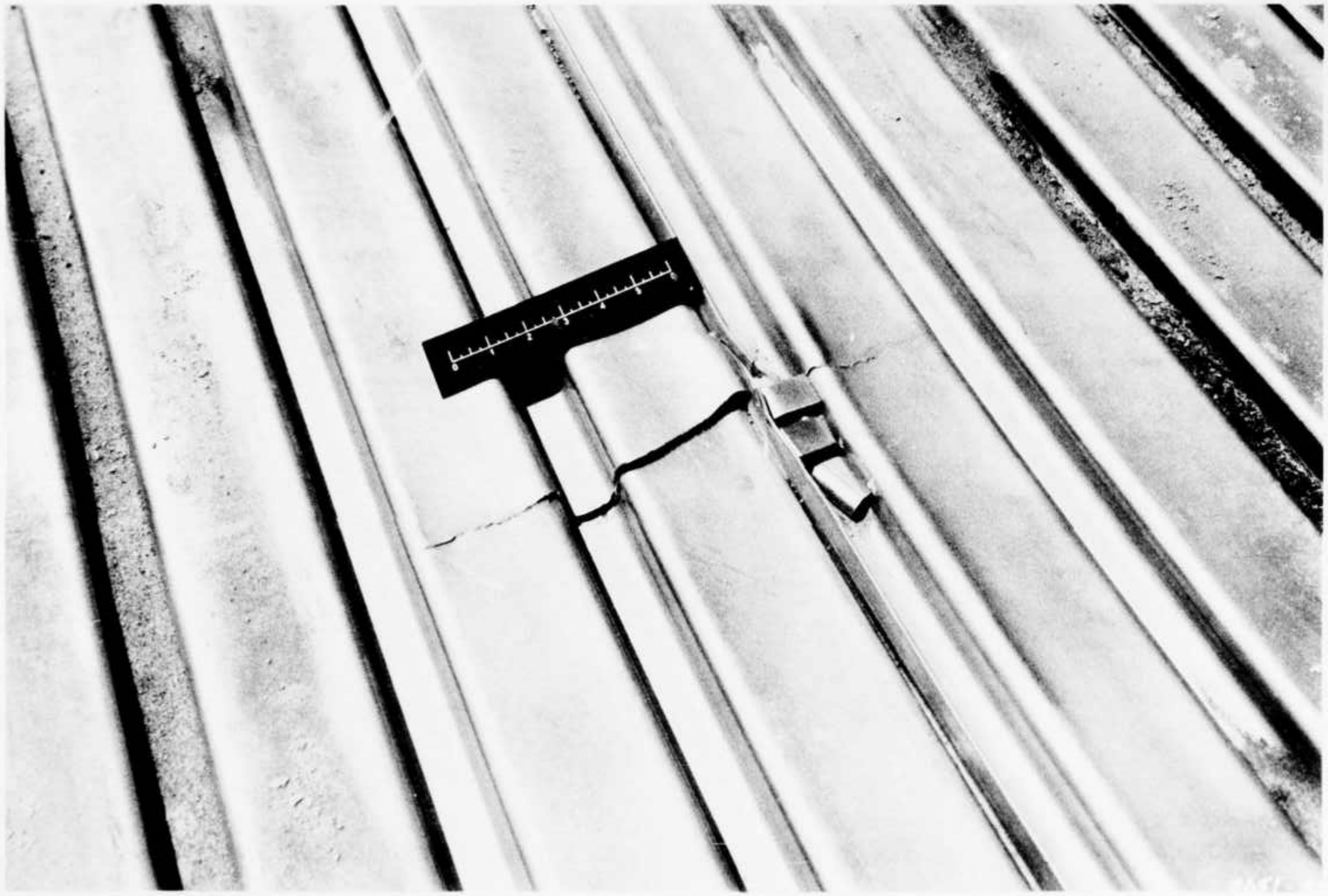


Photo 19. Split in Fletcher panel 43 after 3000 passes

Photo 20. Item 4, test section 1; M8A1 panels prior to traffic

Photo 21. M8A1 in excellent condition at 200 passes

Photo 22. M8A1 at 3000 passes in excellent condition; no failure

Photo 23. Item 5, test section 2; M. C. Gill sandwich panels prior to traffic

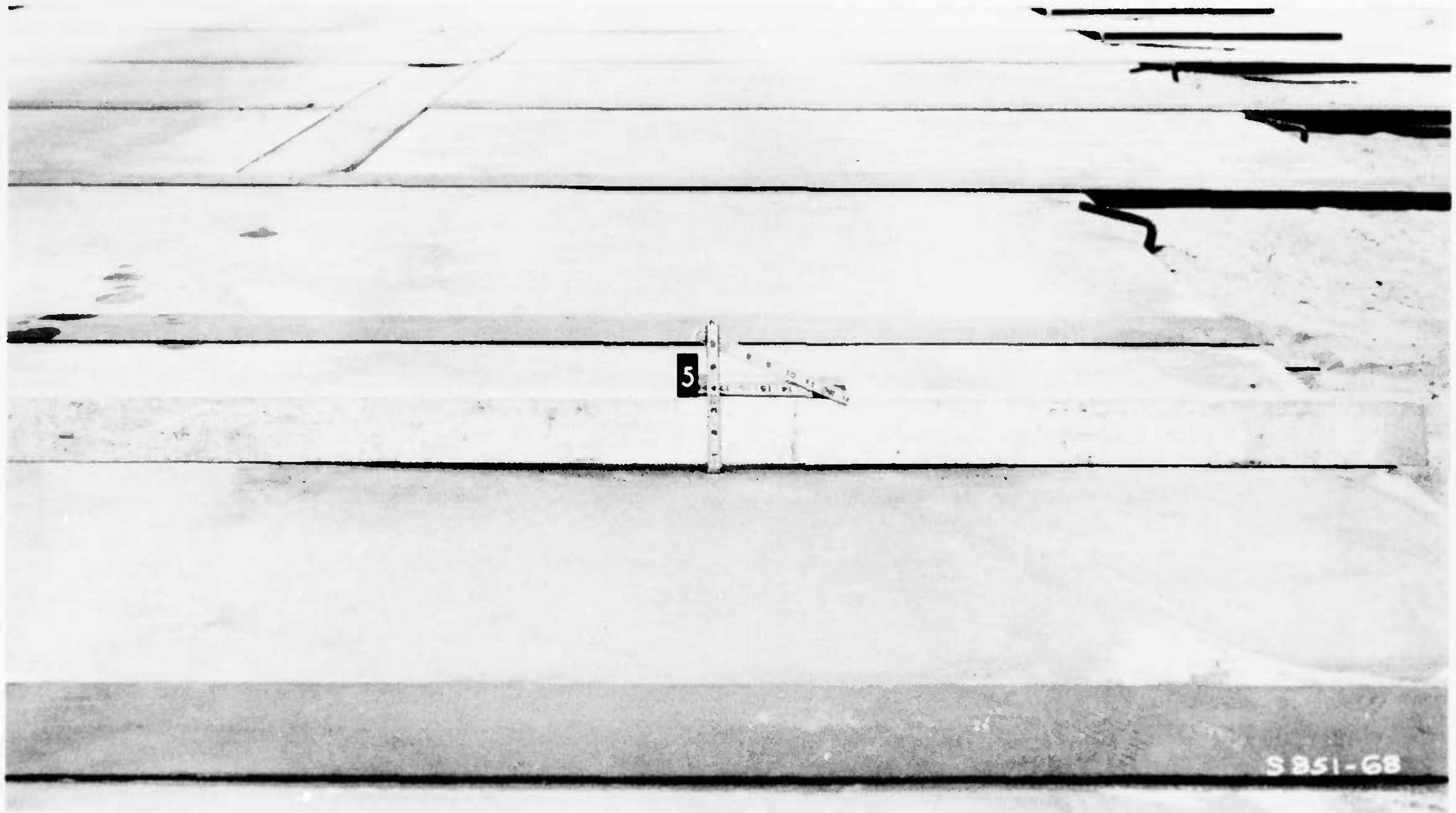


Photo 24. M. C. Gill panel 3 deformed 1/4 in. at 1000 passes

Photo 25. General view of failed M. C. Gill mat section at 2000 passes

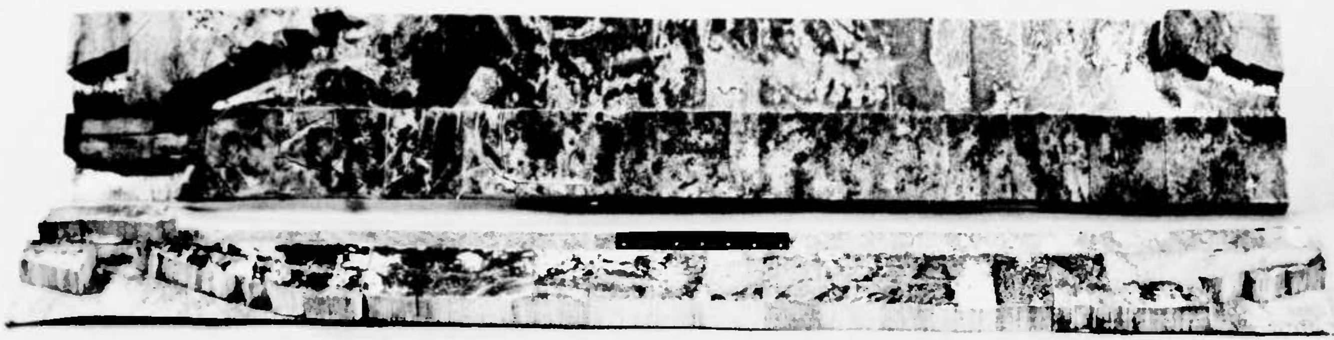


Photo 26. Cross section of failed M. C. Gill balsa wood panel

Photo 27. Kaiser 3.0- and 2.5-lb panels, item 6 (left, south) and item 7 (right, north), respectively, prior to traffic

Photo 28. Kaiser panels at 1000 passes; no failures (3.0-lb panels at left and 2.5-lb panels at right)

Photo 29. Kaiser panels in good condition at 2000 passes (left, 3.0-lb panels; and right, 2.5-lb panels)

Photo 30. Kaiser panels at 3000 passes (end of traffic test); no failures (3.0-lb panels at left and 2.5-lb panels at right)

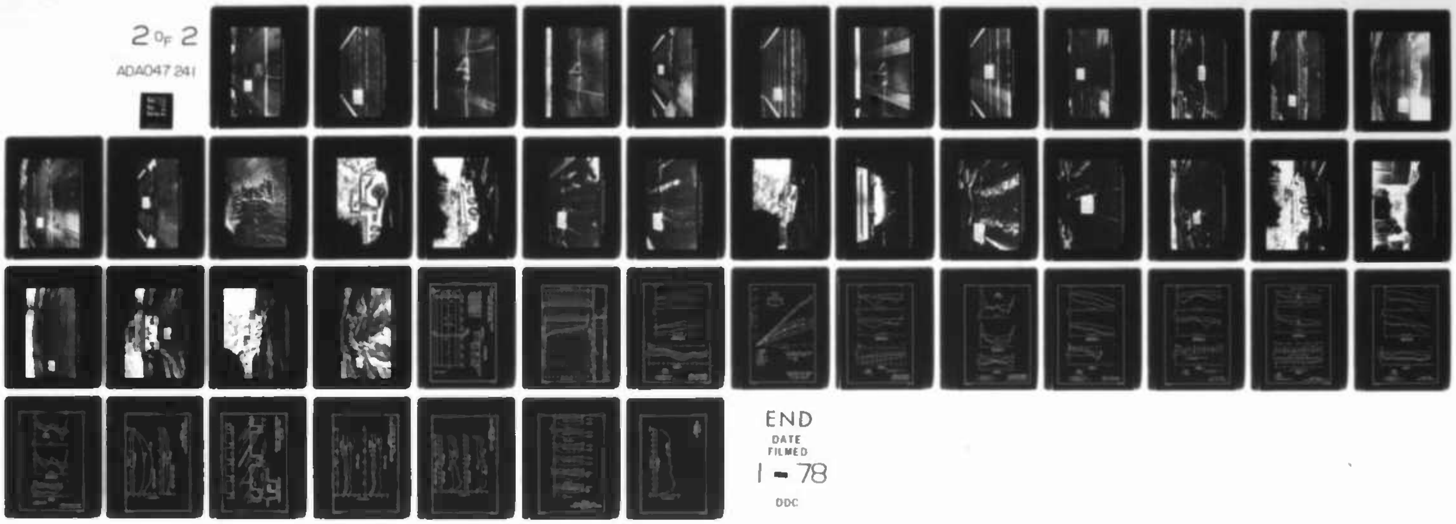
Photo 31. Item 8, test section 2; Alcoa panels prior to traffic

Photo 32. Alcoa panels at 1000 passes; no failures

AD-A047 241 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/3
PRELIMINARY INVESTIGATION OF GENERAL-PURPOSE MAT/PANEL MATERIAL--ETC(U)
MAY 77 H L GREEN, D W WHITE, G L CARR

UNCLASSIFIED WES-MP-S-77-9 NL

2 OF 2
ADA047 241



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1 - 78
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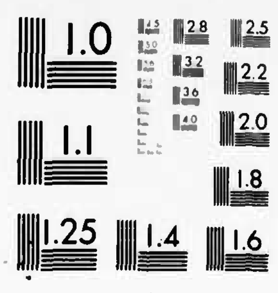
2 OF 2

ADA047 241



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963

Photo 33. Alcoa panels at 3000 passes (end of traffic test); no failures

Photo 34. Item 10, test section 3; Spur-Ecolite one-skin panels with skin down and core filled with sand prior to traffic

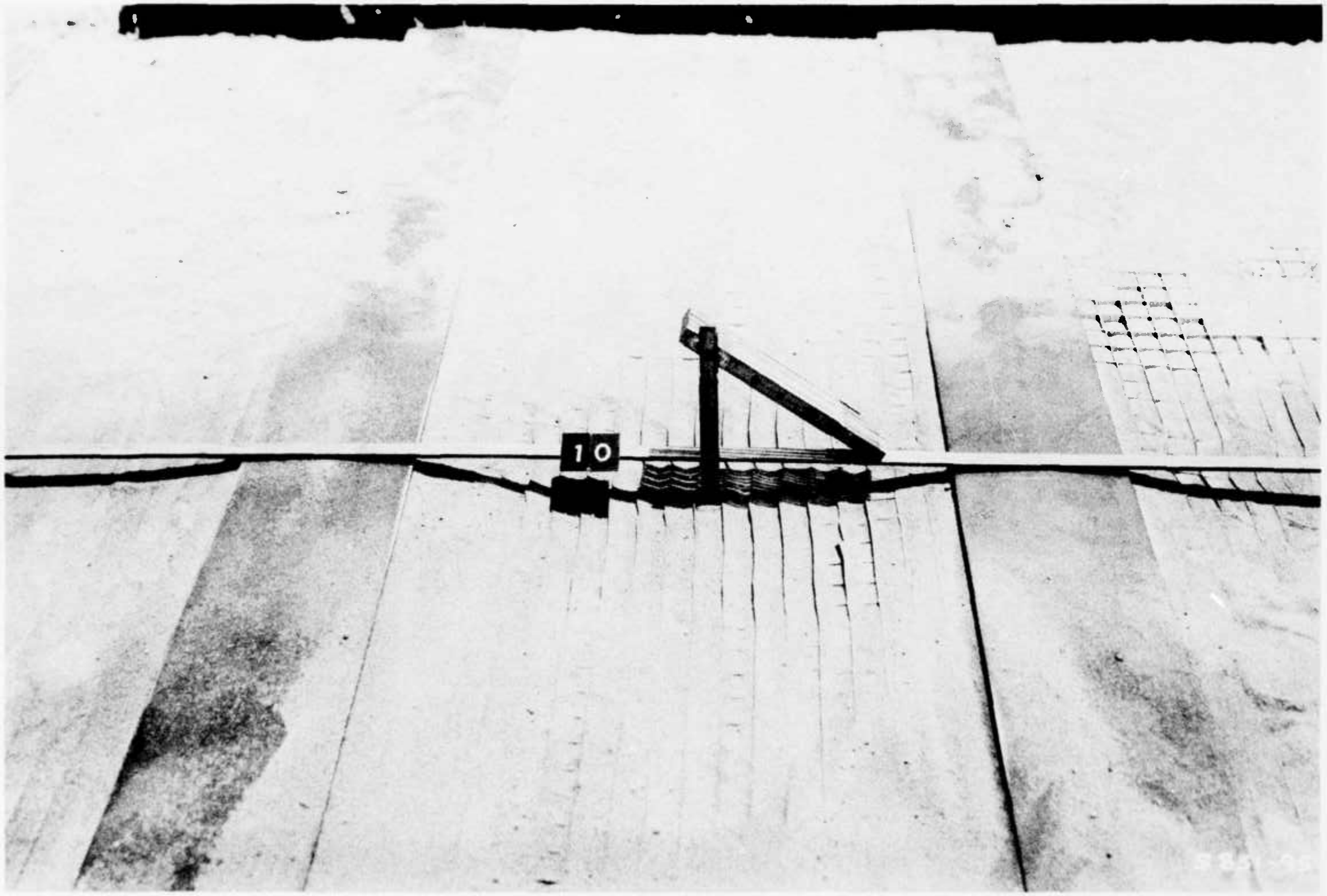


Photo 35. Spur-Ecolite core ribbons distorted and beginning to fail at 200 passes

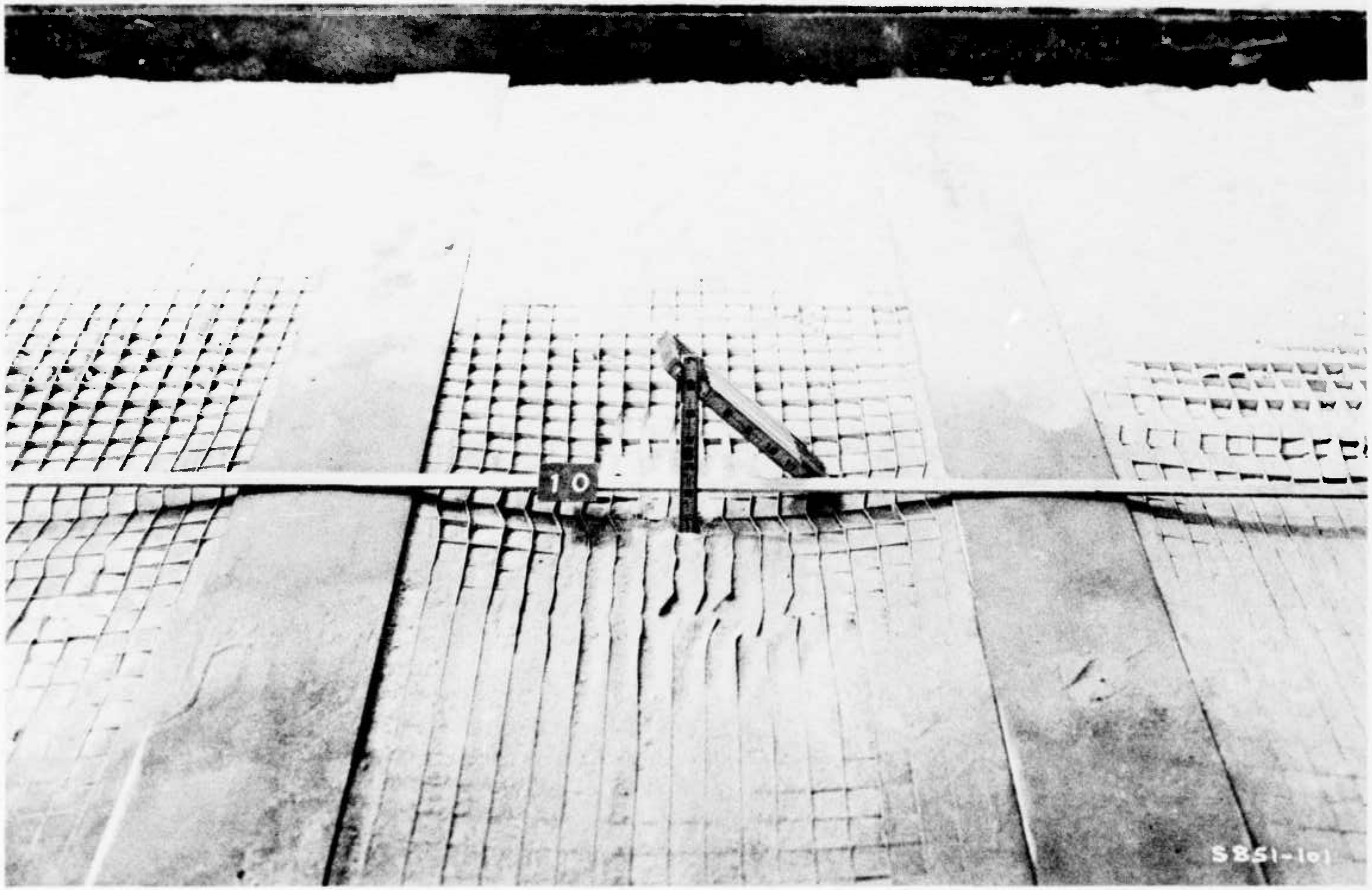


Photo 36. Spur-Ecolite core ribbons distorted and broken at 300 passes; item considered failed

Photo 37. Failed Spur-Ecolite item 10 at 300 passes

Photo 38. Item 11, test section 3; Spur-Ecolite sandwich panels connected with H connectors prior to traffic

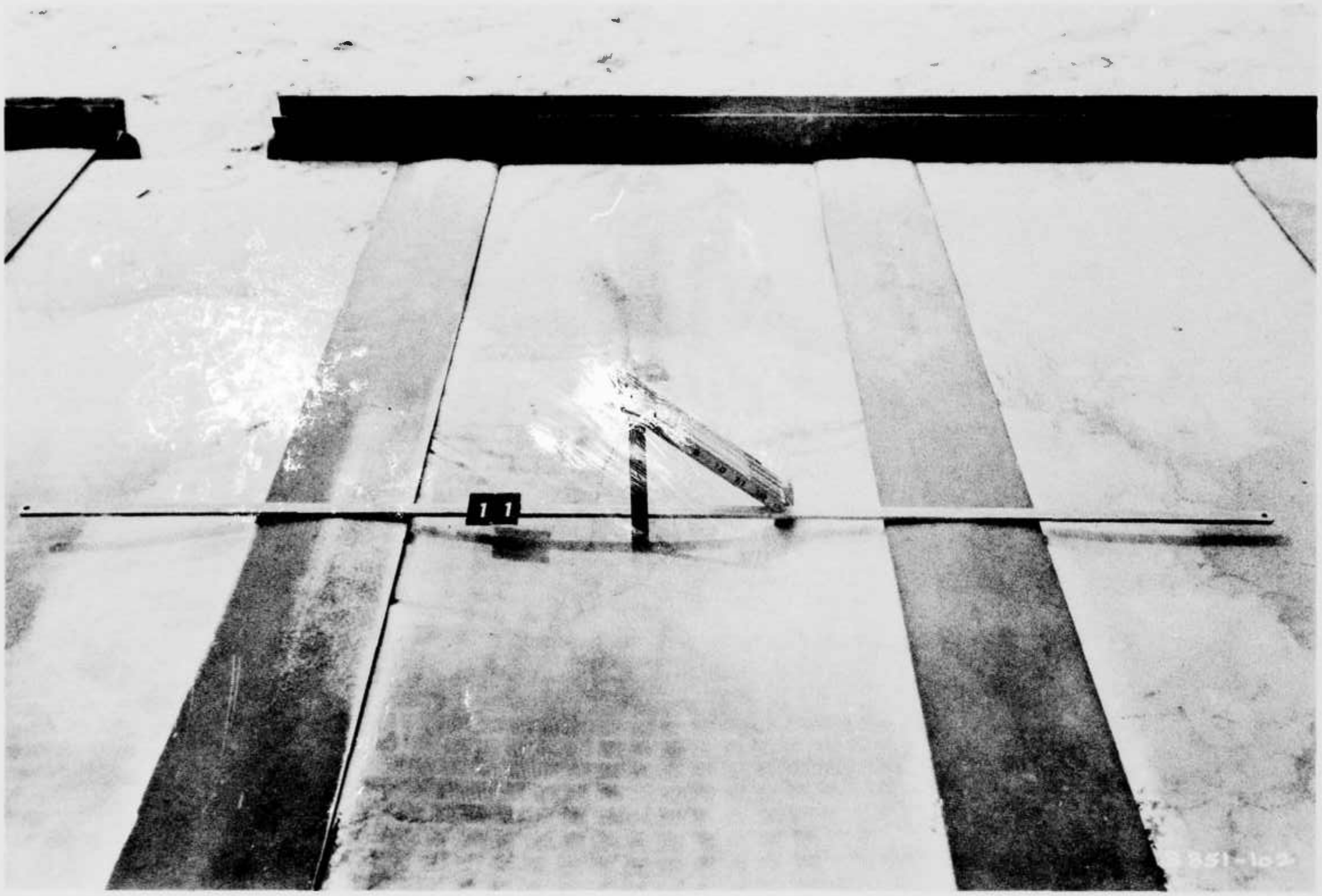


Photo 39. Transverse dishing of 1 in. on Spur-Ecolite sandwich panel at 200 passes

Photo 40. Failed Spur-Ecolite item 11 at 300 passes

Photo 41. With H connectors removed, the top skins of the Spur-Ecolite sandwich panels are shown disbonded in wheel paths at 300 passes

Photo 42. Items 21 and 22, Spur-Ecolite one-skin panels; failed item 21 (left) with skin up and unfailed item 22 (right) with skin down at 80 passes

Photo 43. Item 24, test section 4; Woodside formed aluminum panels prior to traffic

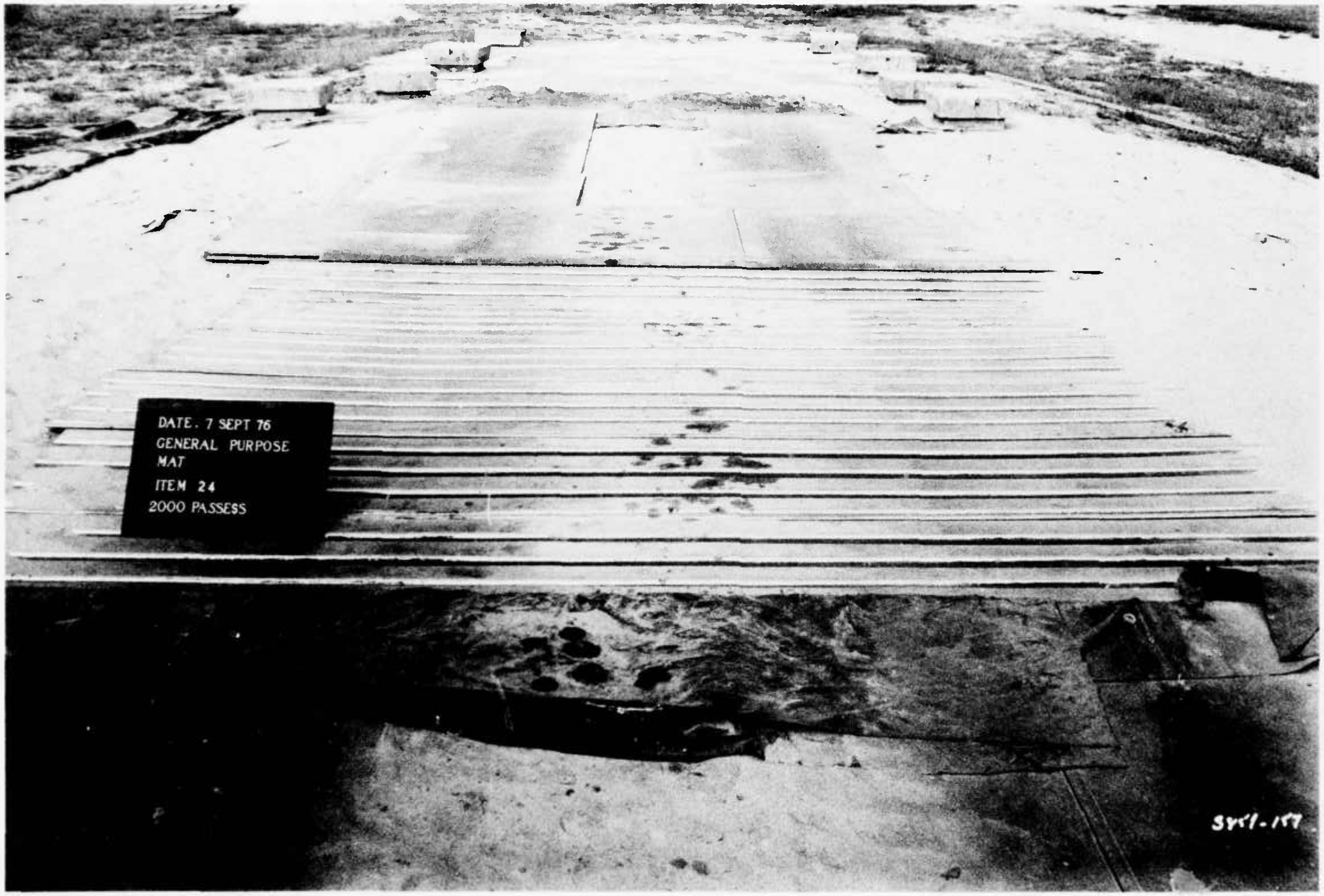


Photo 44. Woodside panels in excellent condition at 2000 passes

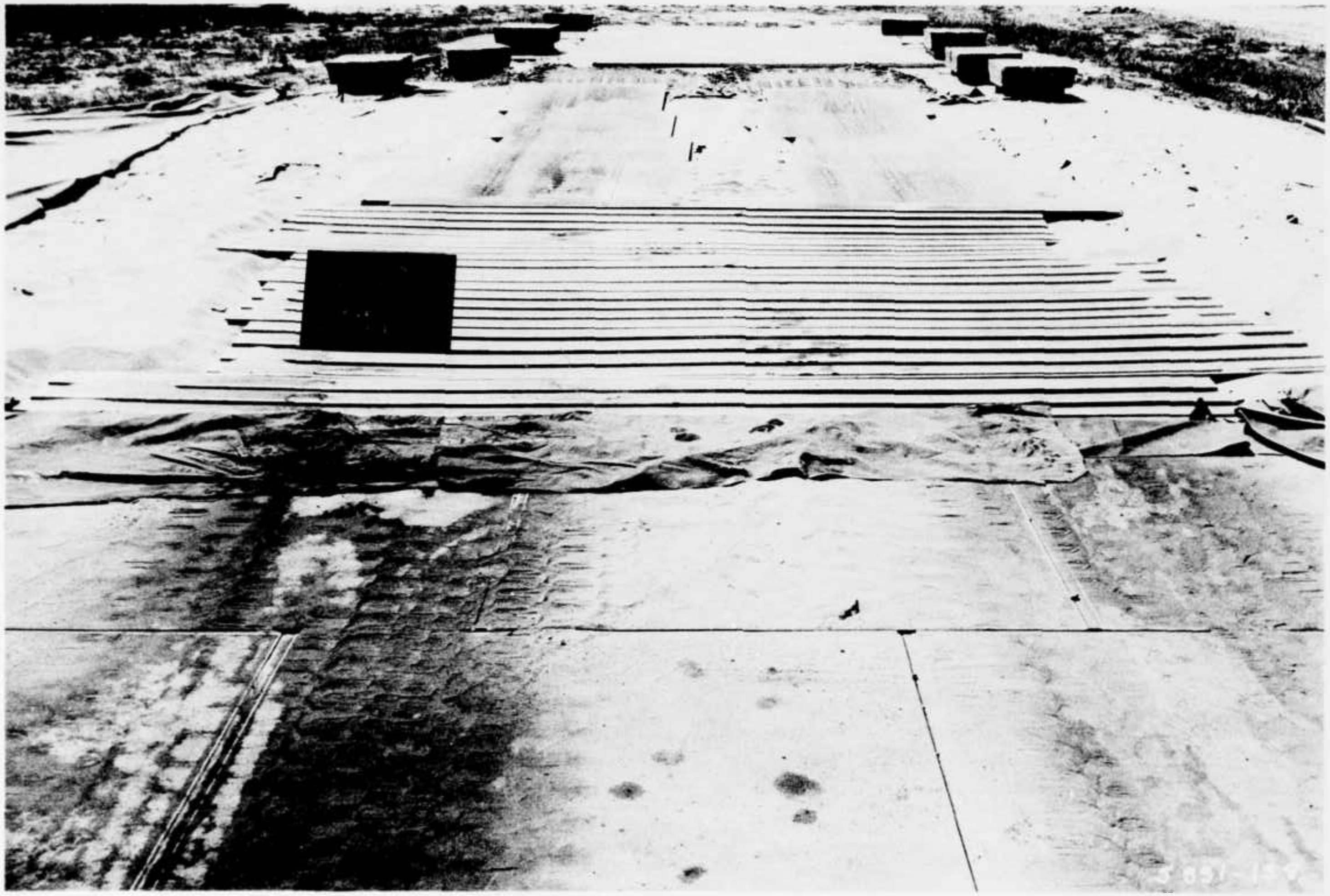


Photo 45. Woodside panels in excellent condition at 3000 passes (end of traffic test); no failure

Photo 46. Ecolite 1- by 1-in. core, item 9, at 200 passes

Photo 47. Ecolite 1- by 1-in. core, item 9, at 300 passes. Note torn and flattened core ribbons

Photo 48. Ecolite 1- by 1-in. grid placed longitudinal to traffic direction prior to traffic

Photo 49. Ecolite grid broken and distorted when load truck pulled up on it from the immobilizing sand

Photo 50. Hexcel paper honeycomb core, 1-1/2-in. cells, 2 in. thick, in double layers, item 16 (north), after 3 passes

Photo 51. Hexcel paper honeycomb core, 3-in. cells, 2 in. thick, in double layers, item 17 (south), after 3 passes

Photo 52. M54 truck, 40,000-lb gross load, on items 16 and 17, fourth pass

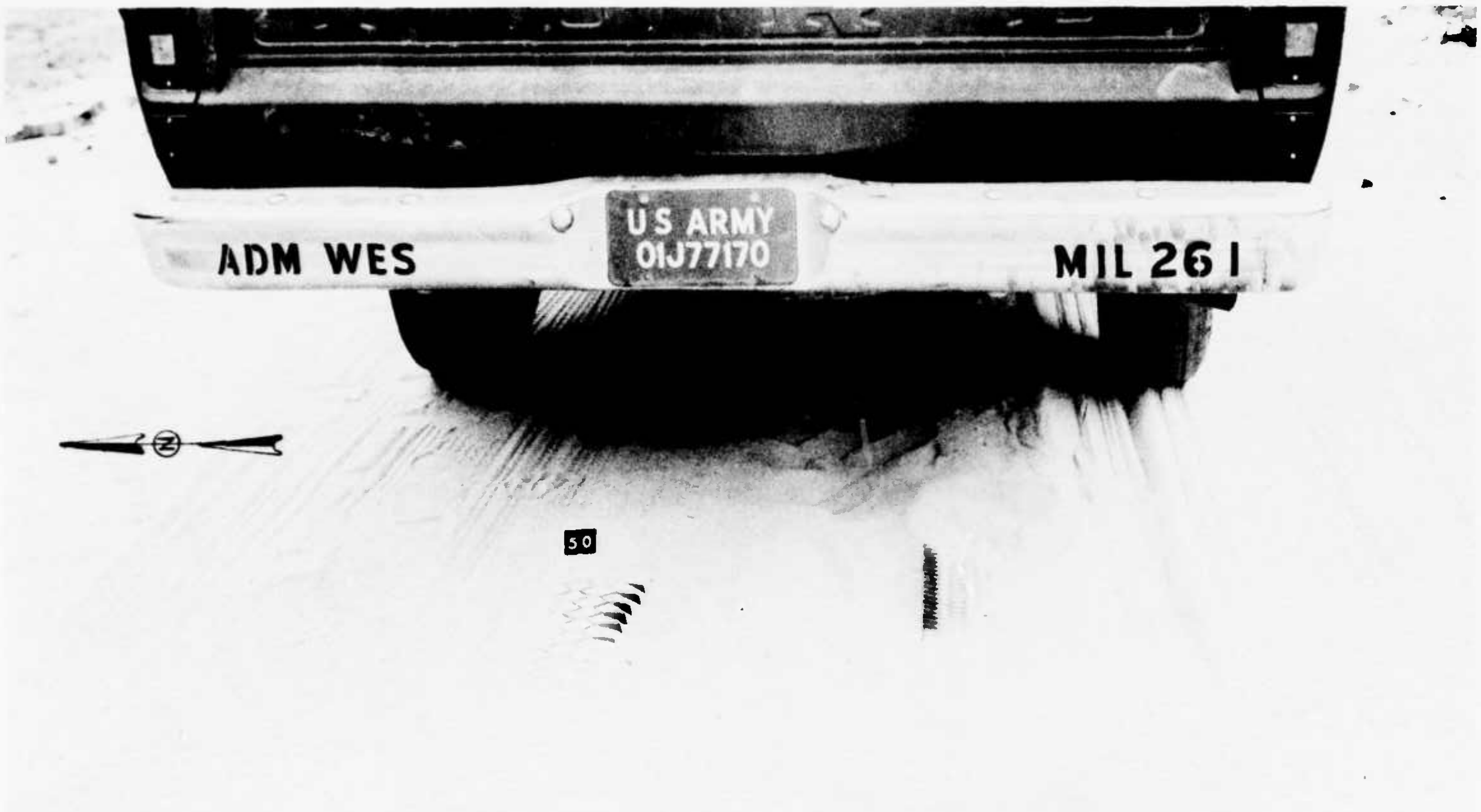


Photo 53. Hexcel paper honeycomb core, double layers after 50 passes of a 3700-lb pickup truck. The 1-1/2- and 3/4-in. cells are shown left to right (north to south), respectively

Photo 54. Hexcel paper honeycomb core, item 18, double layer of 1-1/2-in. cells, considered failed after 400 passes of mixed vehicular traffic

Photo 55. Hexcel paper honeycomb core, item 19 (left), double layer of 3/4-in. cells, in good condition after 400 passes of mixed vehicular traffic

Photo 56. Hexcel paper honeycomb core, item 19, double layer of 3/4-in. cells, after 2000 passes of mixed vehicular traffic

Photo 57. M54 truck with a gross weight of 40,000 lb immobilized in loose dry sand on first pass

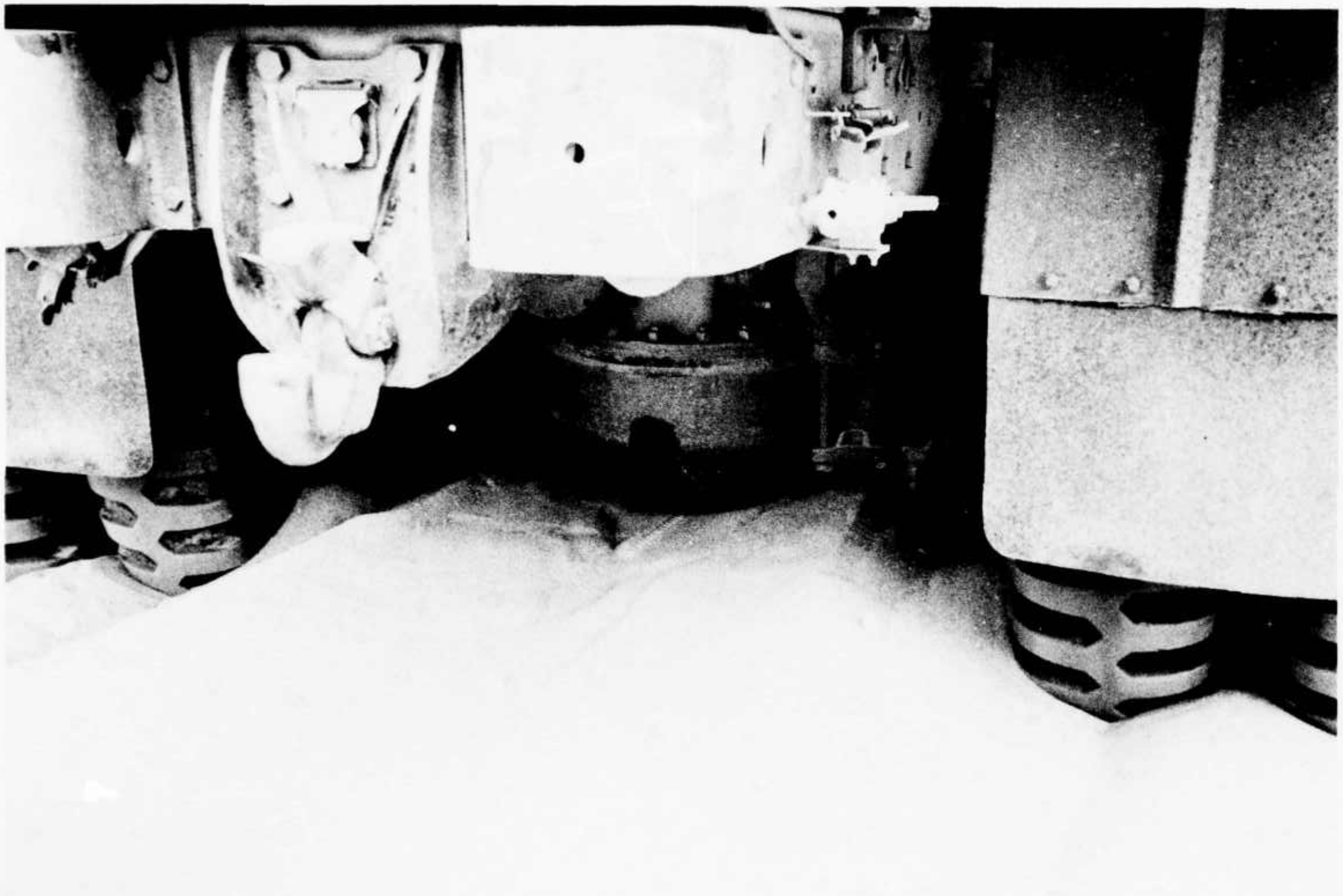


Photo 58. M54 truck with gross weight of 40,000 lb showing undercarriage dragging in sand on first pass

Photo 59. Item 20, T16 membrane on dry loose sand prior to traffic

Photo 60. M54 truck on T16 membrane, first pass

Photo 61. M54 truck on WX18 membrane at 8 passes. Note that membrane edge has been pulled toward the ruts by action of the wheels

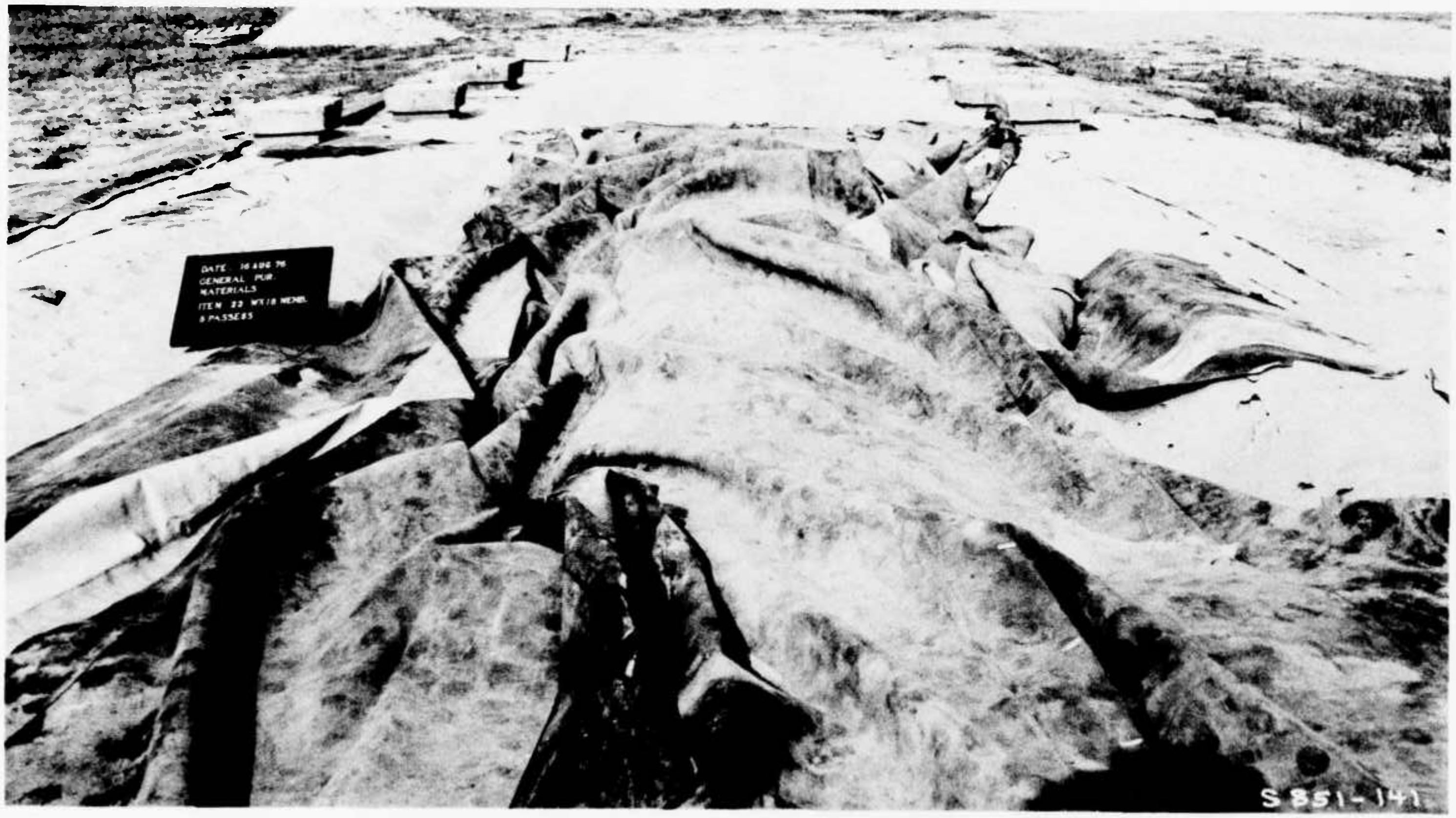


Photo 62. Item 23, WX18 membrane after 8 passes. Note wrinkles and membrane edge in wheel ruts

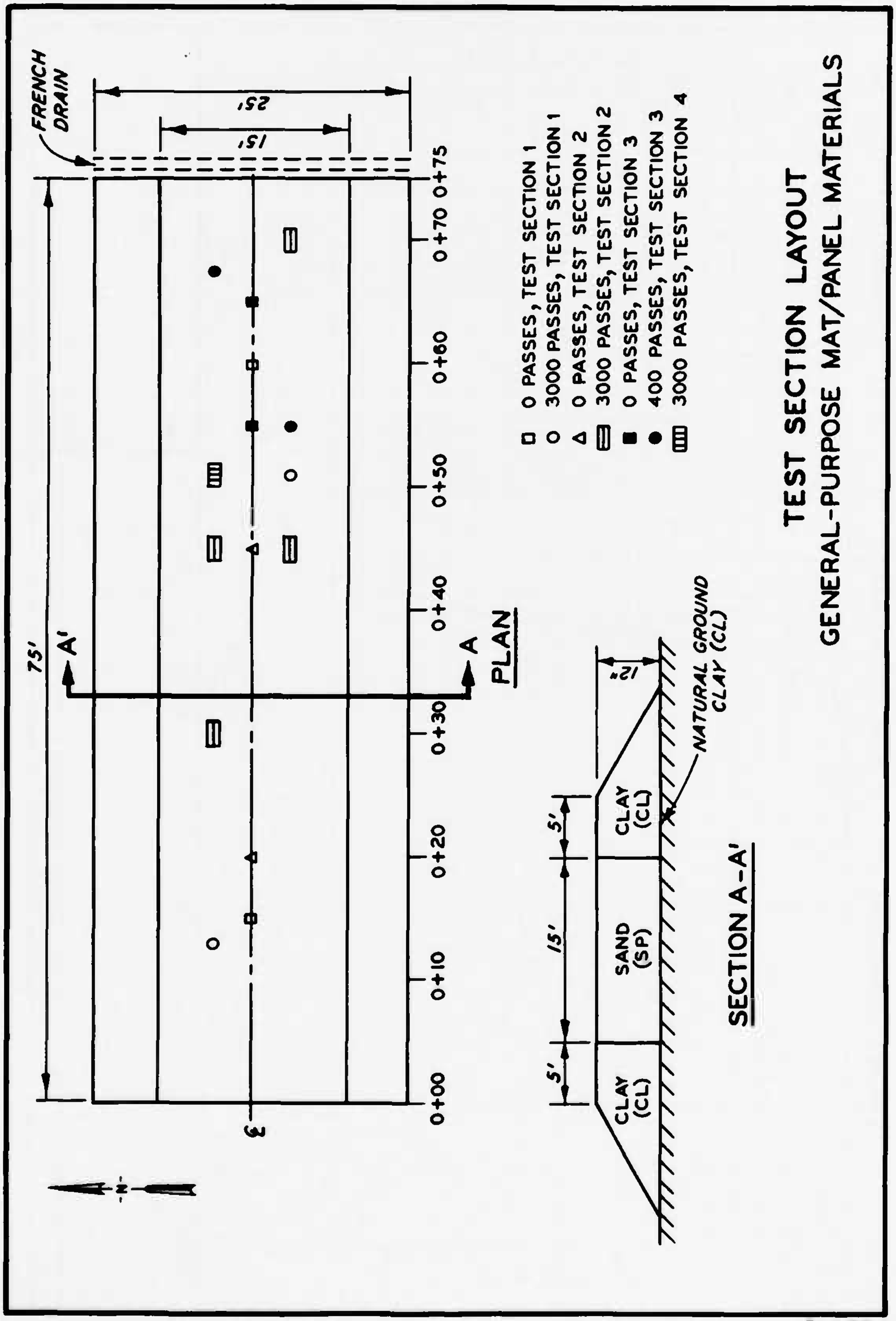

FRENCH DRAIN
25'
15'
75'
A'
A
0+00
0+10
0+20
0+30
0+40
0+50
0+60
0+70
0+75
℄
PLAN
0 PASSES, TEST SECTION 1
3000 PASSES, TEST SECTION 1
0 PASSES, TEST SECTION 2
3000 PASSES, TEST SECTION 2
0 PASSES, TEST SECTION 3
400 PASSES, TEST SECTION 3
3000 PASSES, TEST SECTION 4
5'
15'
5'
12"
CLAY (CL)
SAND (SP)
CLAY (CL)
NATURAL GROUND CLAY (CL)
SECTION A-A'
TEST SECTION LAYOUT
GENERAL-PURPOSE MAT/PANEL MATERIALS

PLATE 1

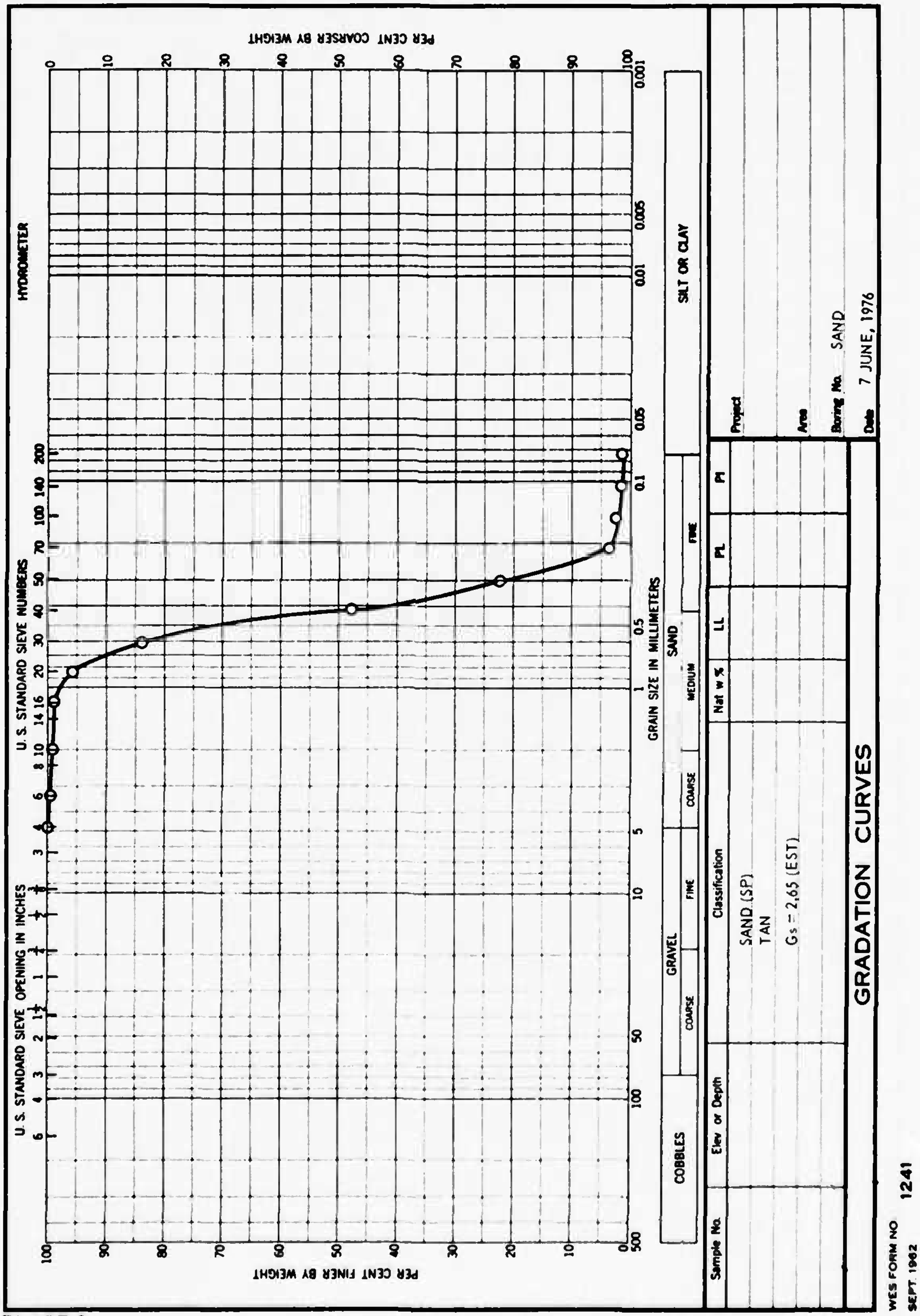
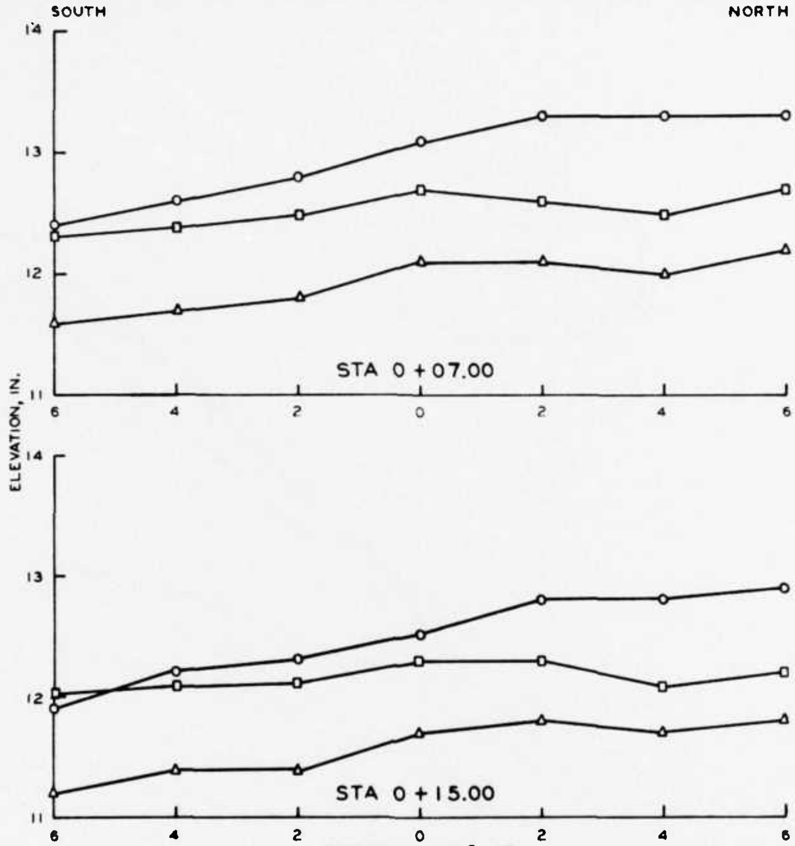
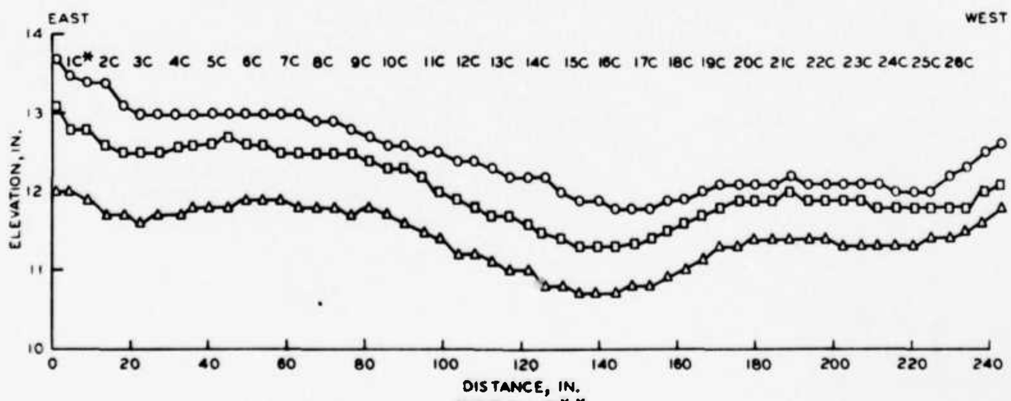

U. S. STANDARD SIEVE OPENING IN INCHES
U. S. STANDARD SIEVE NUMBERS
HYDROMETER
PER CENT FINER BY WEIGHT
PER CENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
COBBLES
GRAVEL
COARSE
FINE
SAND
COARSE
MEDIUM
FINE
SILT OR CLAY
Sample No.
Elev or Depth
Classification
Nat w %
LL
PL
PI
SAND (SP)
TAN
Gs = 2.65 (EST)
Project
Area
Boring No. SAND
Date 7 JUNE, 1976
GRADATION CURVES
WES FORM NO 1241
SEPT. 1962

PLATE 2



CROSS SECTION



PROFILE**

LEGEND

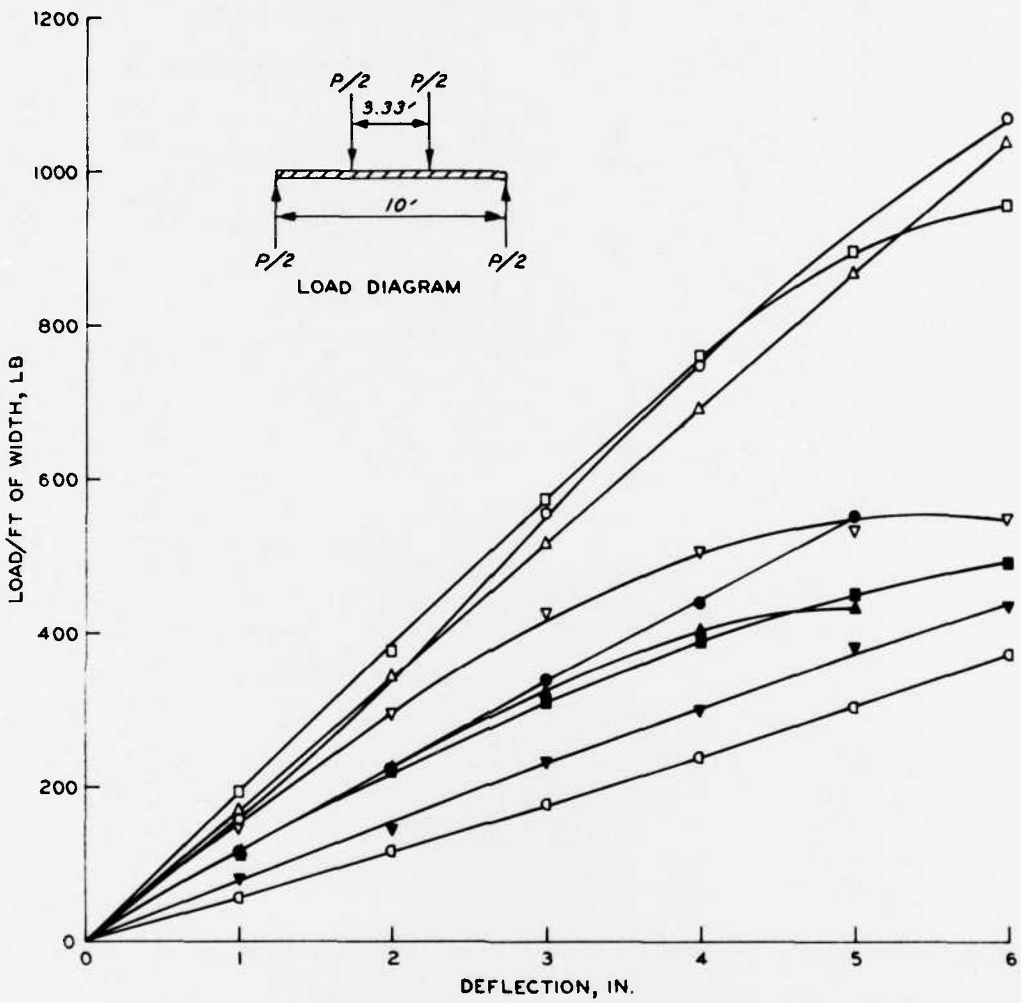
- O 0 PASSES
- □ 200 PASSES
- Δ 3000 PASSES

* PANEL NUMBER. C DENOTES CENTER OF PANEL

** 3 FEET FROM SOUTH EDGE OF ITEM, IN SOUTH WHEEL PATH

WELLS EXTRUDED ALUMINUM PANELS

ITEM 1, TEST SECTION 1



LEGEND

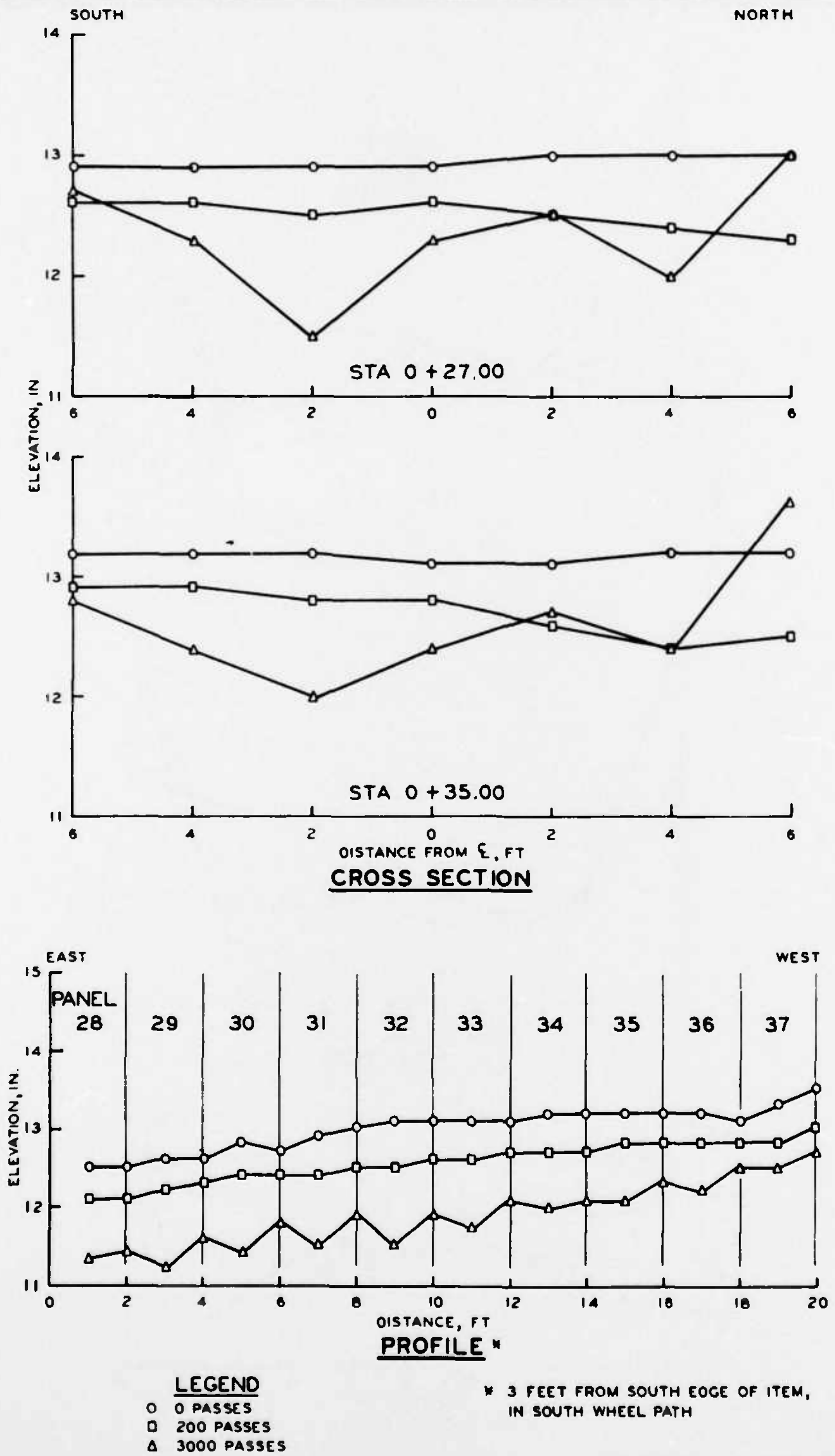
- ○ WOODSIDE
- □ M8A1
- △ ALCOA
- ▽ KAISER (3.0) *
- ● TABER
- ▲ KAISER (2.5) *
- ■ FLETCHER
- ▼ WELLS
- ◌ M. C. GILL

* TESTED USING A LENGTH OF 80 INCHES. DATA CONVERTED TO A LENGTH OF 10 FEET USING EULER'S FORMULA:

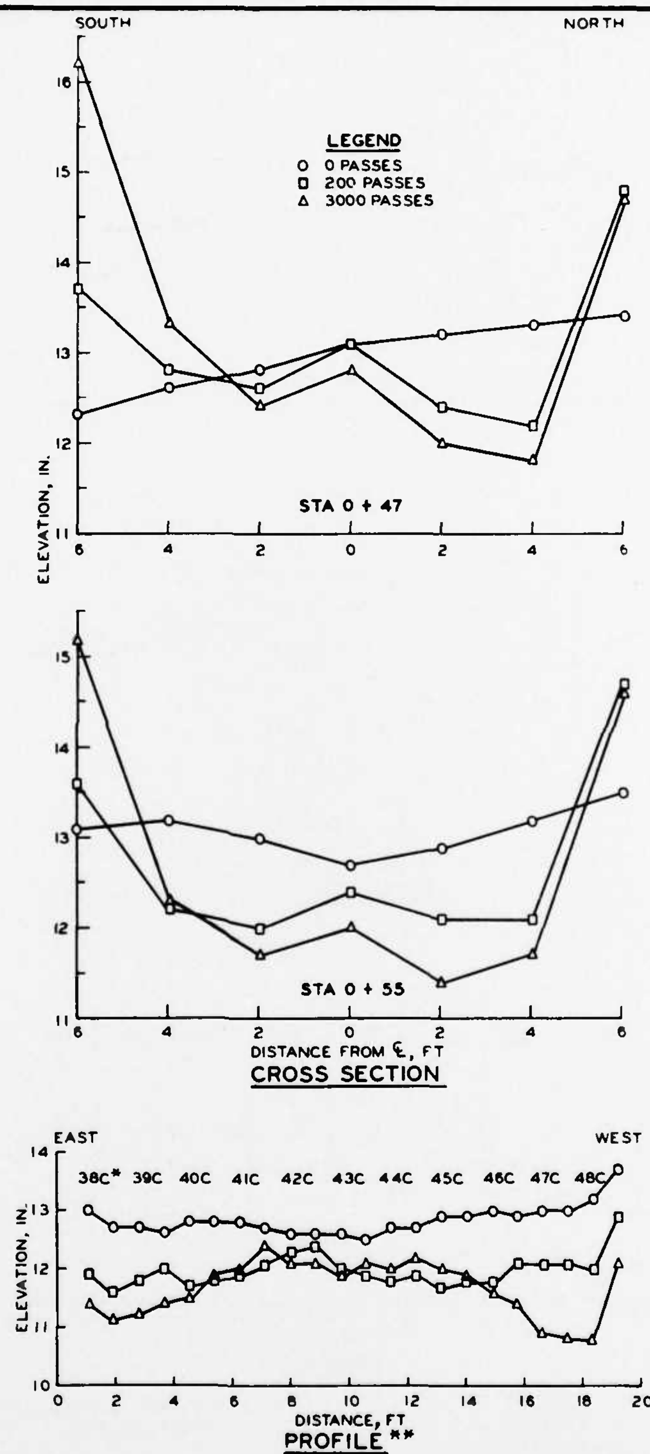
$$\frac{P_c}{A} = \frac{\pi^2 E}{\frac{k^2 L^2}{r^2}}$$

LOAD-DEFLECTION CURVES
BEAM TEST, 10-FT SPAN
1/3-POINT LOADING

PLATE 4



TABER EXTRUDED ALUMINUM PANELS
ITEM 2, TEST SECTION 1

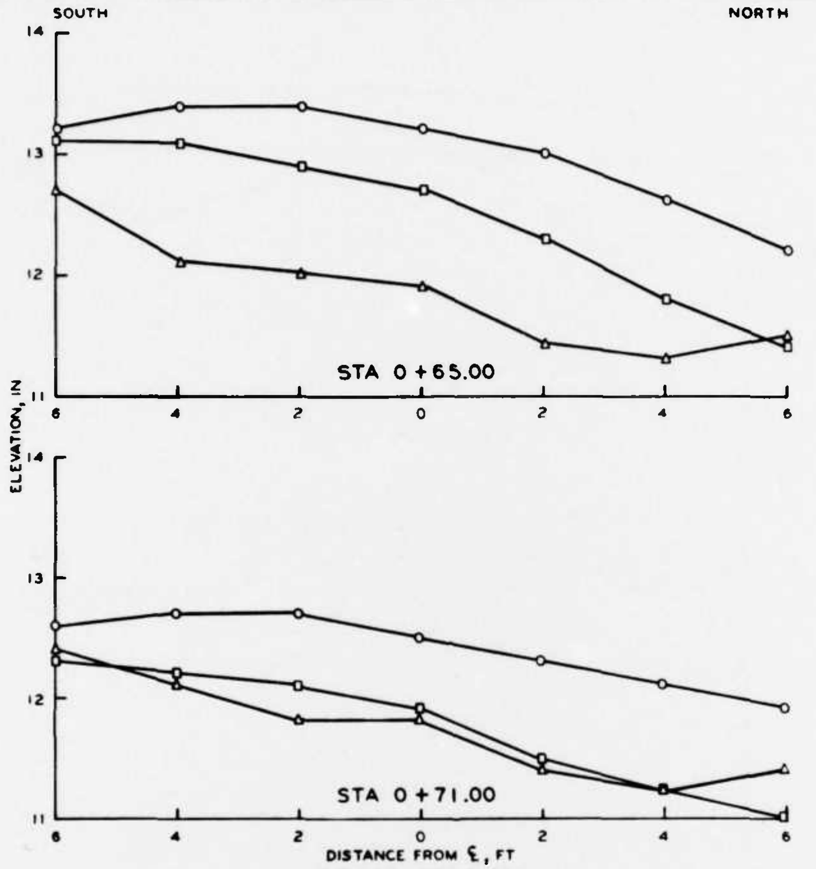


* PANEL NUMBER. C DENOTES CENTER OF PANEL

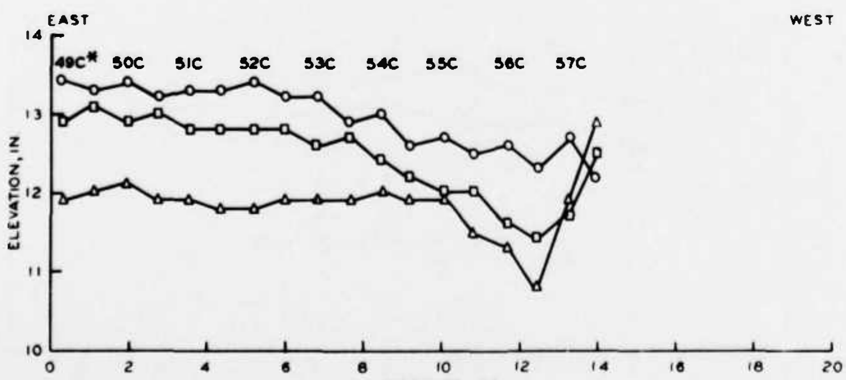
** 3 FEET FROM SOUTH EDGE OF ITEM, IN SOUTH WHEEL PATH

FLETCHER FORMED ALUMINUM PANELS

ITEM 3, TEST SECTION 1



CROSS SECTION



PROFILE**

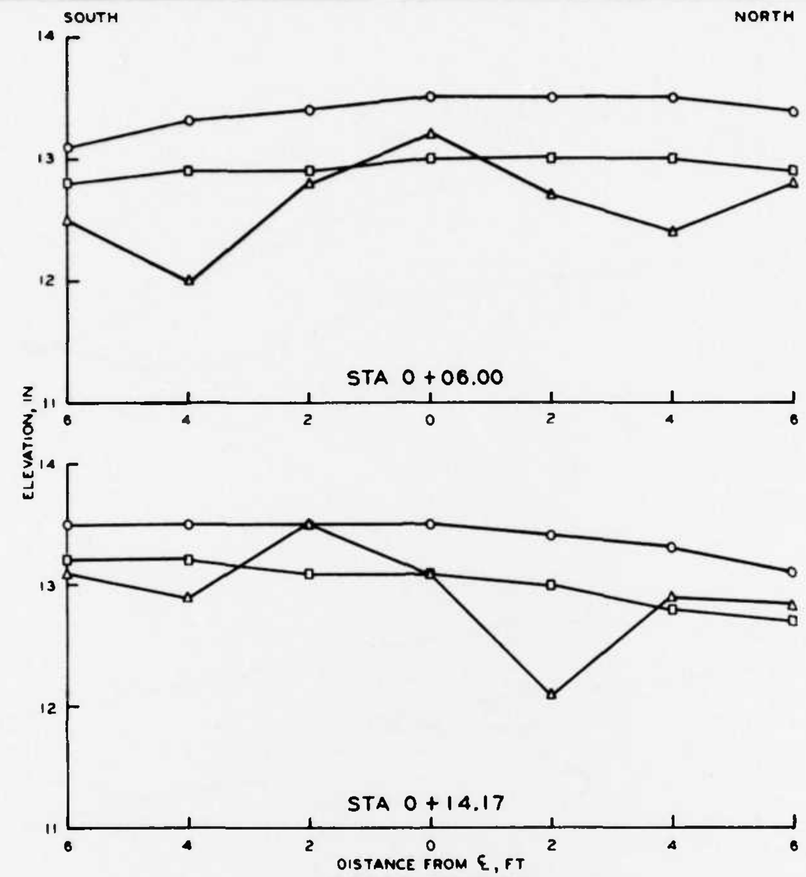
LEGEND

- O 0 PASSES
- □ 200 PASSES
- Δ 3000 PASSES

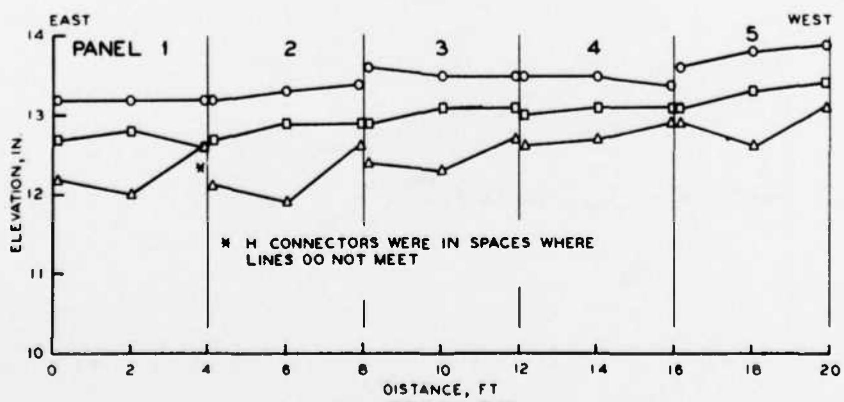
* PANEL NUMBER. C DENOTES CENTER OF PANEL

** 3 FEET FROM SOUTH EDGE OF ITEM, IN SOUTH WHEEL PATH

M8A1 STEEL MAT
ITEM 4, TEST SECTION 1



CROSS SECTION



PROFILE**

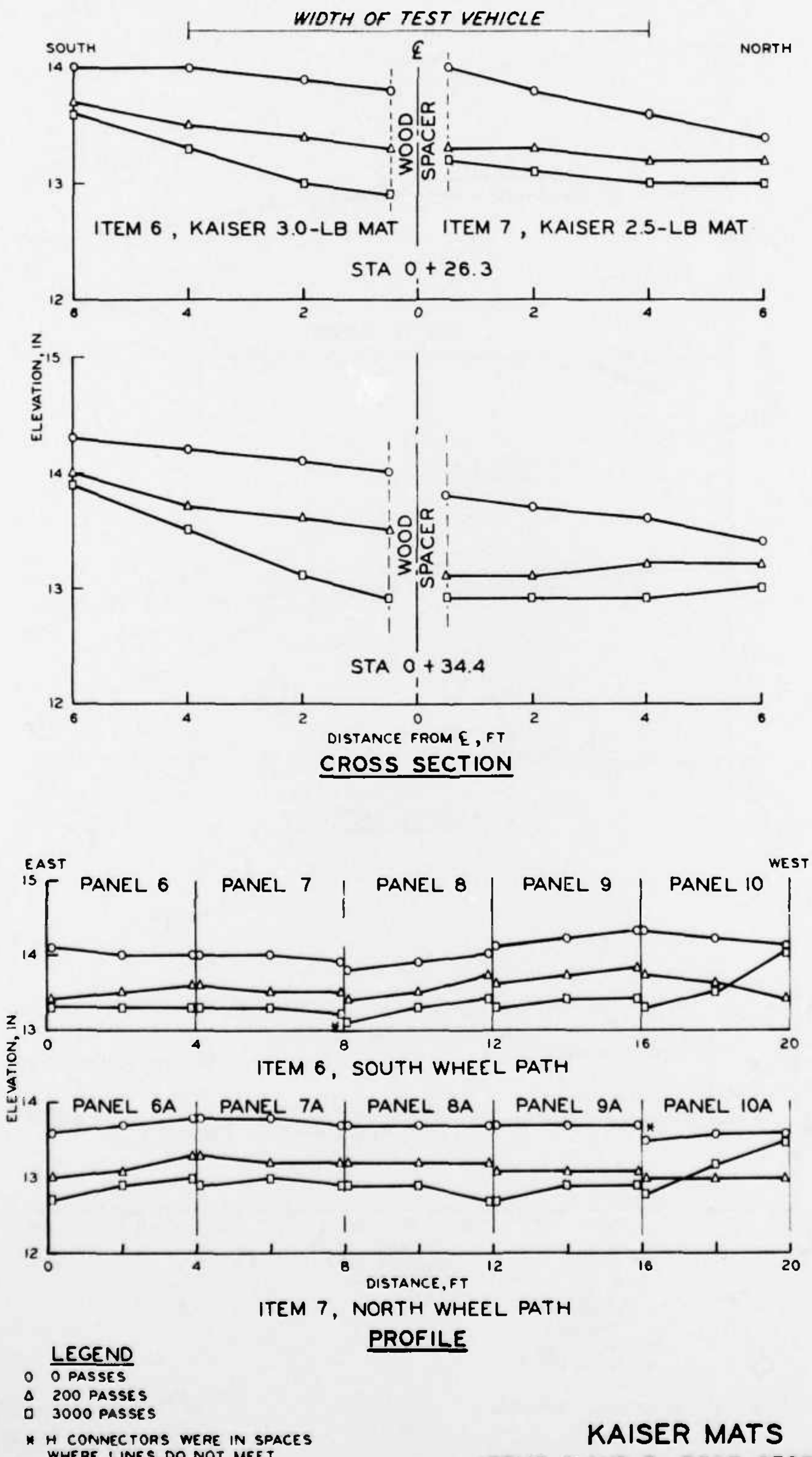
LEGEND

- O 0 PASSES
- □ 200 PASSES
- Δ 2000 PASSES

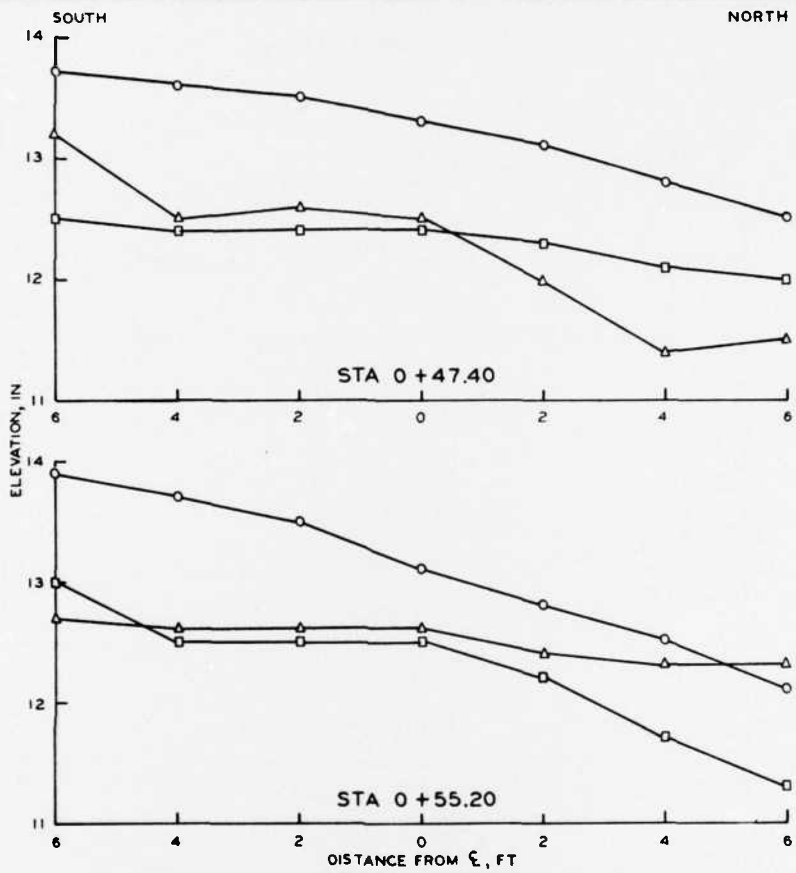
** 3 FEET FROM SOUTH EDGE OF ITEM, IN SOUTH WHEEL PATH

M. C. GILL MAT

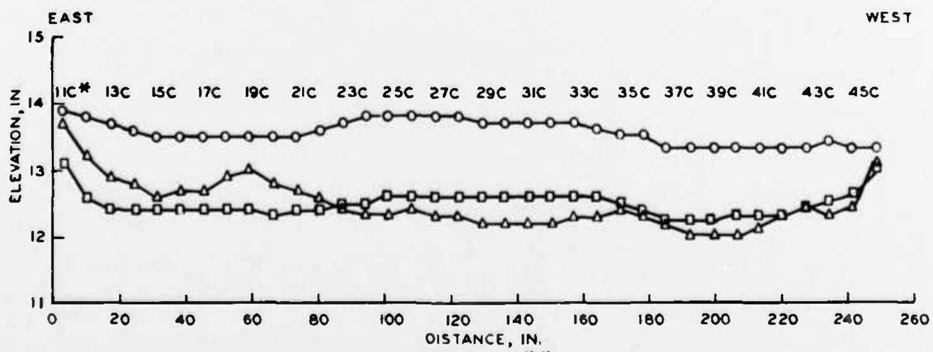
ITEM 5, TEST SECTION 2



KAISER MATS
ITEMS 6 AND 7, TEST SECTION 2



CROSS SECTION



PROFILE**

LEGEND

- O 0 PASSES
- □ 200 PASSES
- Δ 3000 PASSES

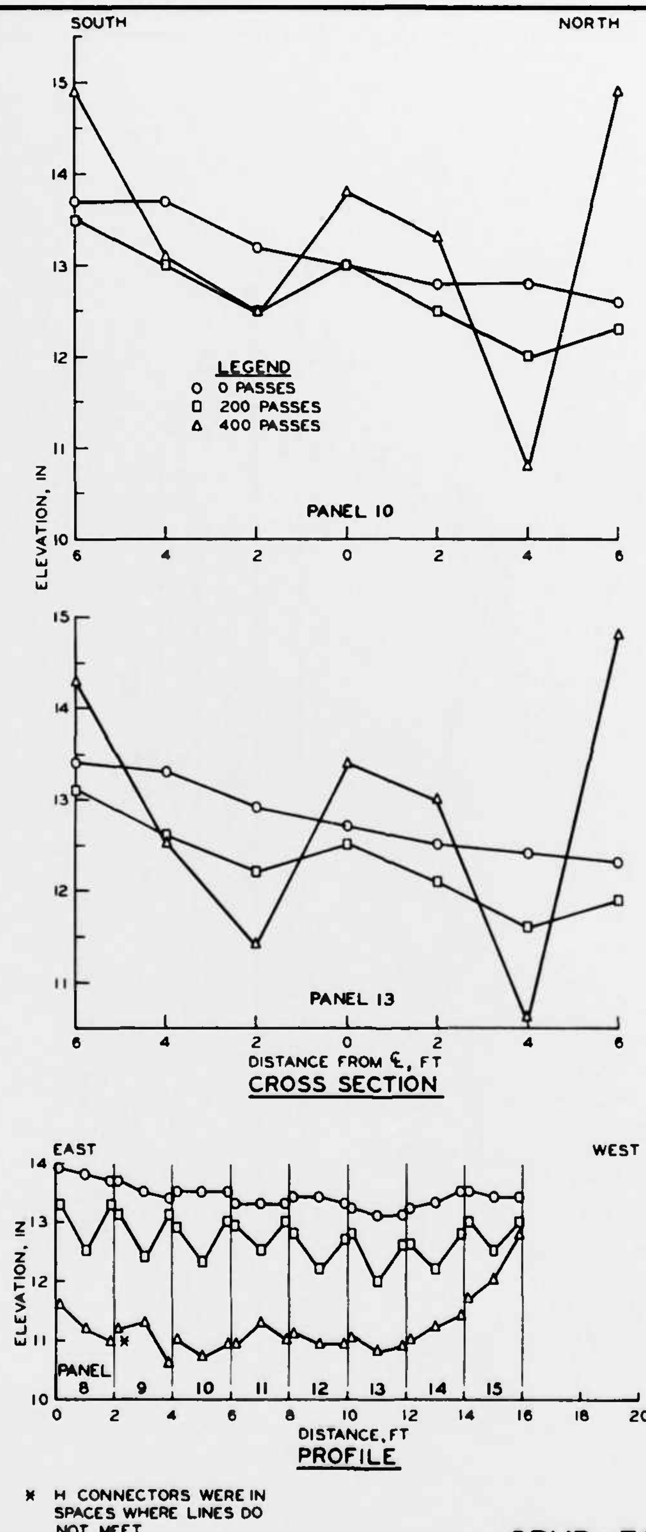
* PANEL NUMBER. C DENOTES CENTER OF PANEL

** 3 FEET FROM SOUTH EDGE OF ITEM, IN SOUTH WHEEL PATH

ALCOA MAT

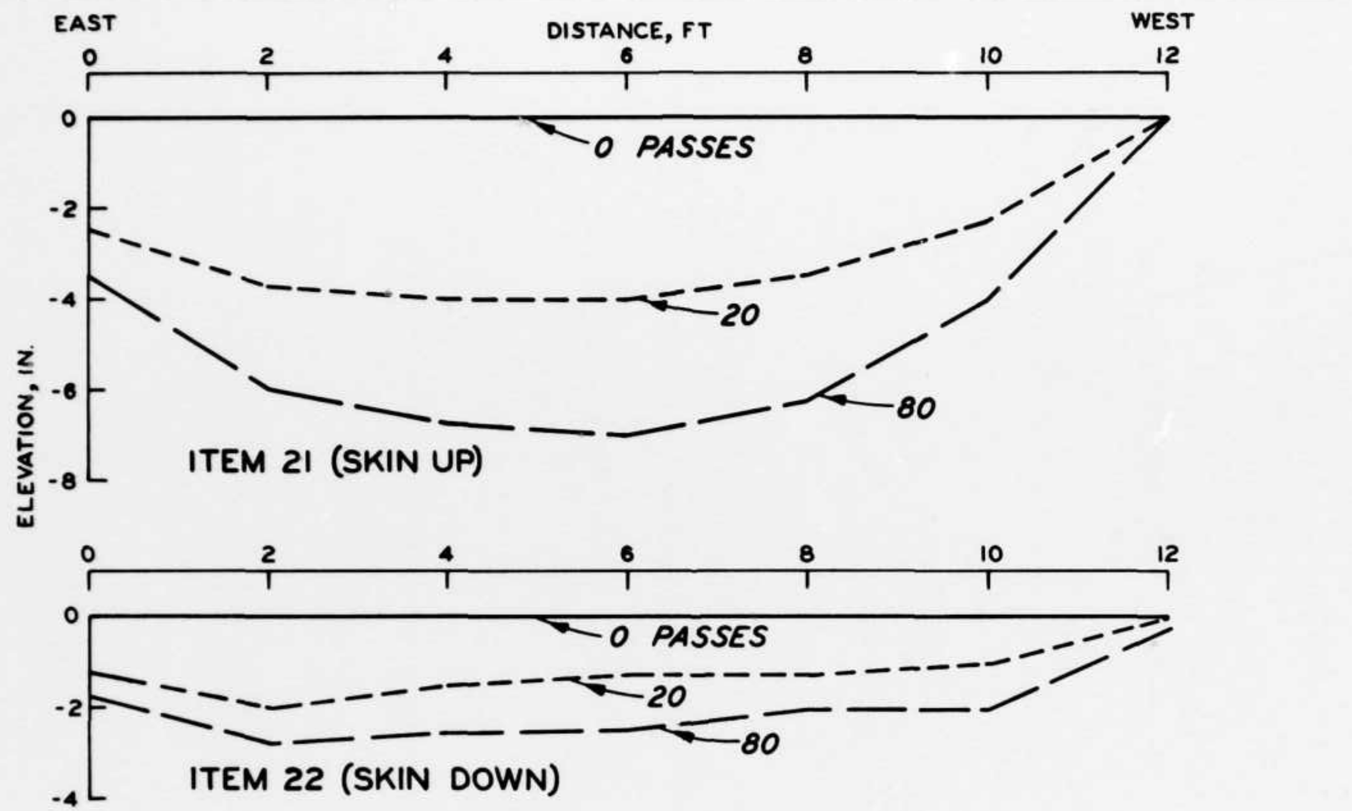
ITEM 8, TEST SECTION 2

PLATE 10

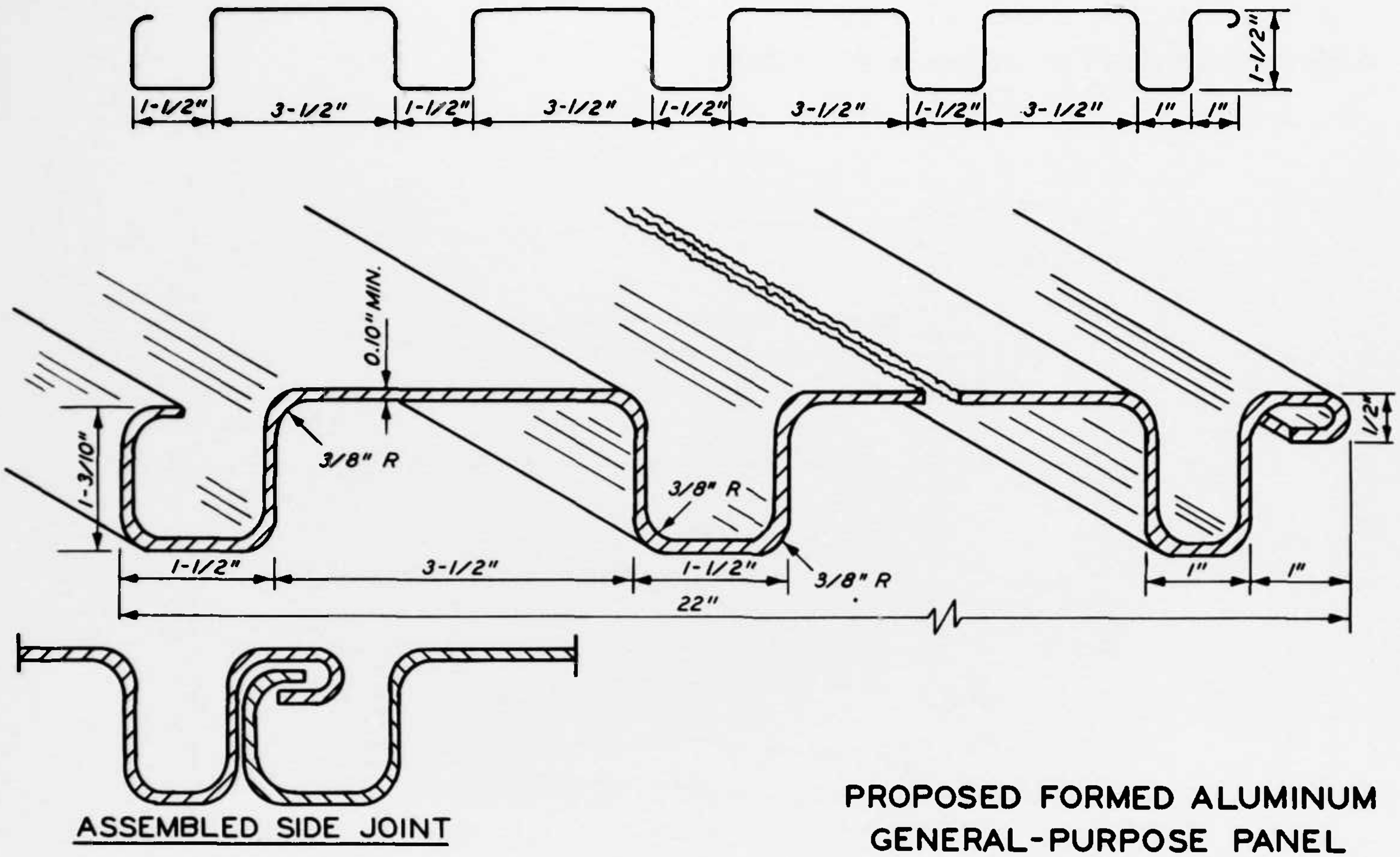


SPUR-ECOLITE MAT

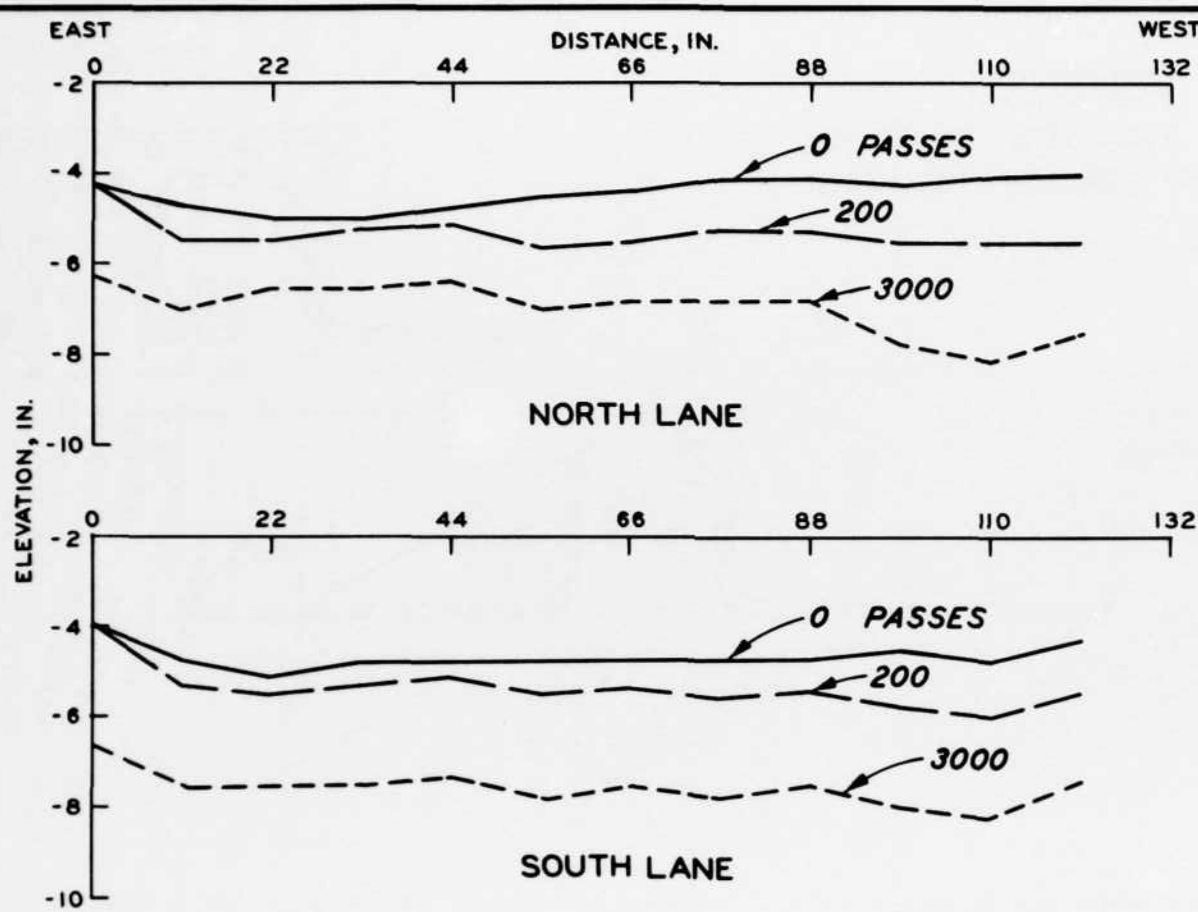
ITEM 11, TEST SECTION 3



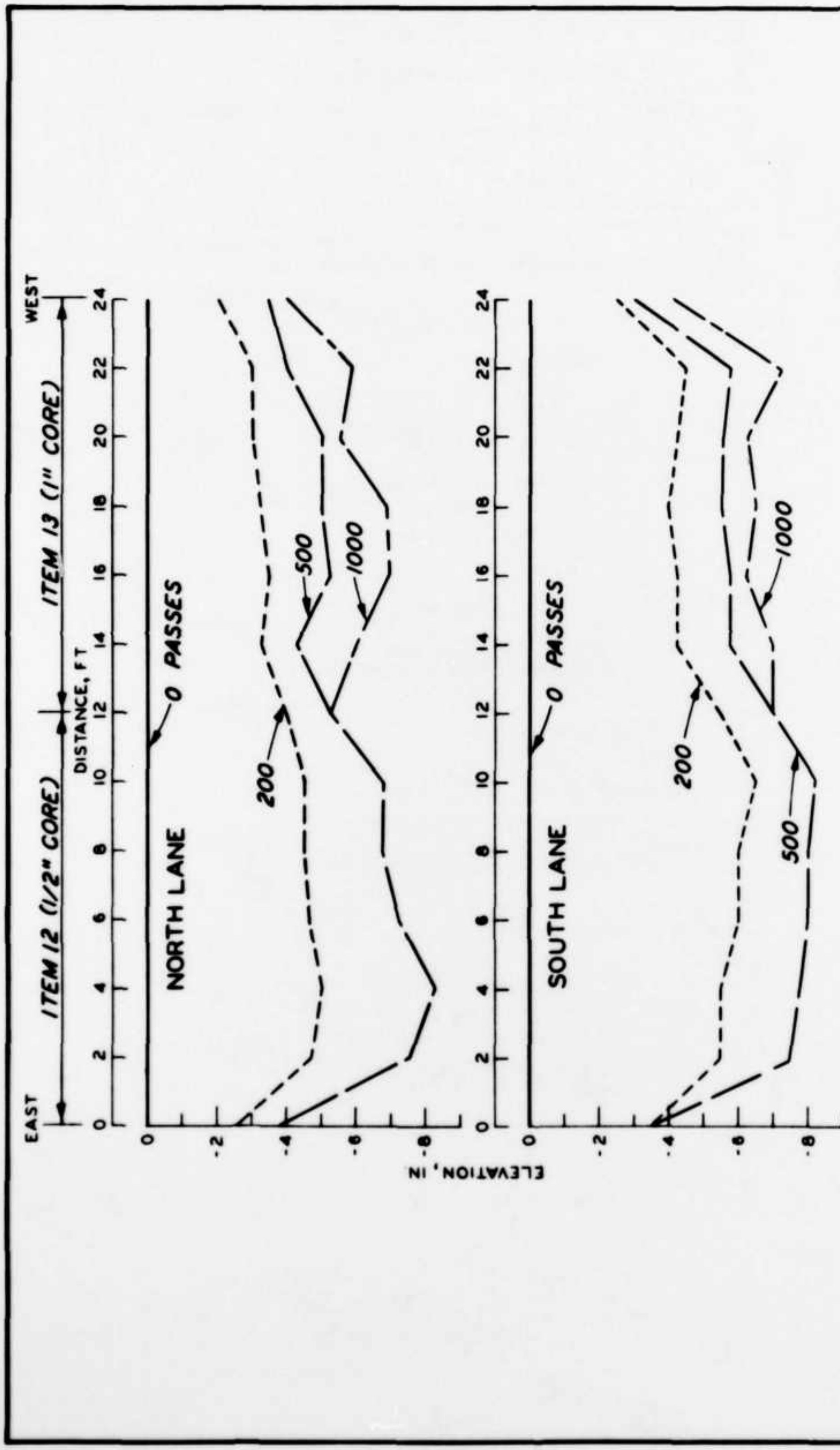
PROFILE
SPUR - ECOLITE MATS
ITEMS 21 AND 22, TEST SECTION 3



PROPOSED FORMED ALUMINUM GENERAL-PURPOSE PANEL
(NOT TO SCALE)
AUGUST 1975

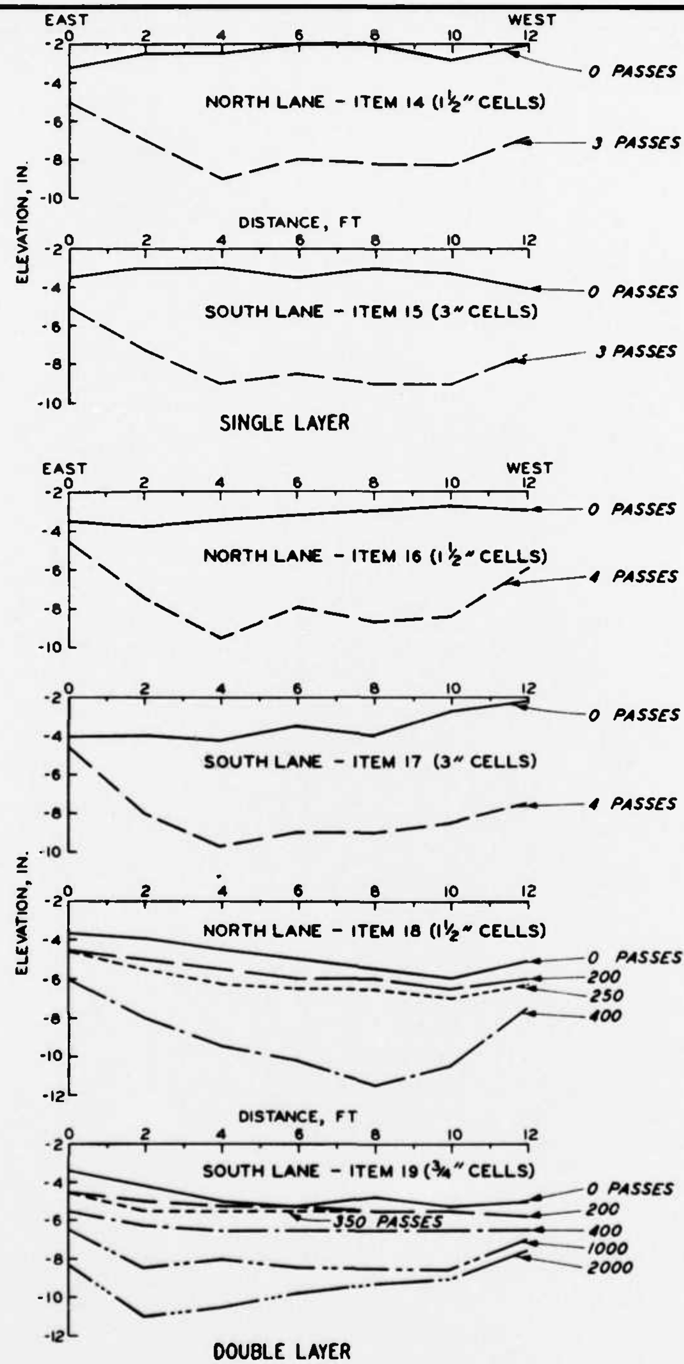


PROFILE
WOODSIDE FORMED ALUMINUM PANELS
ITEM 24, TEST SECTION 4

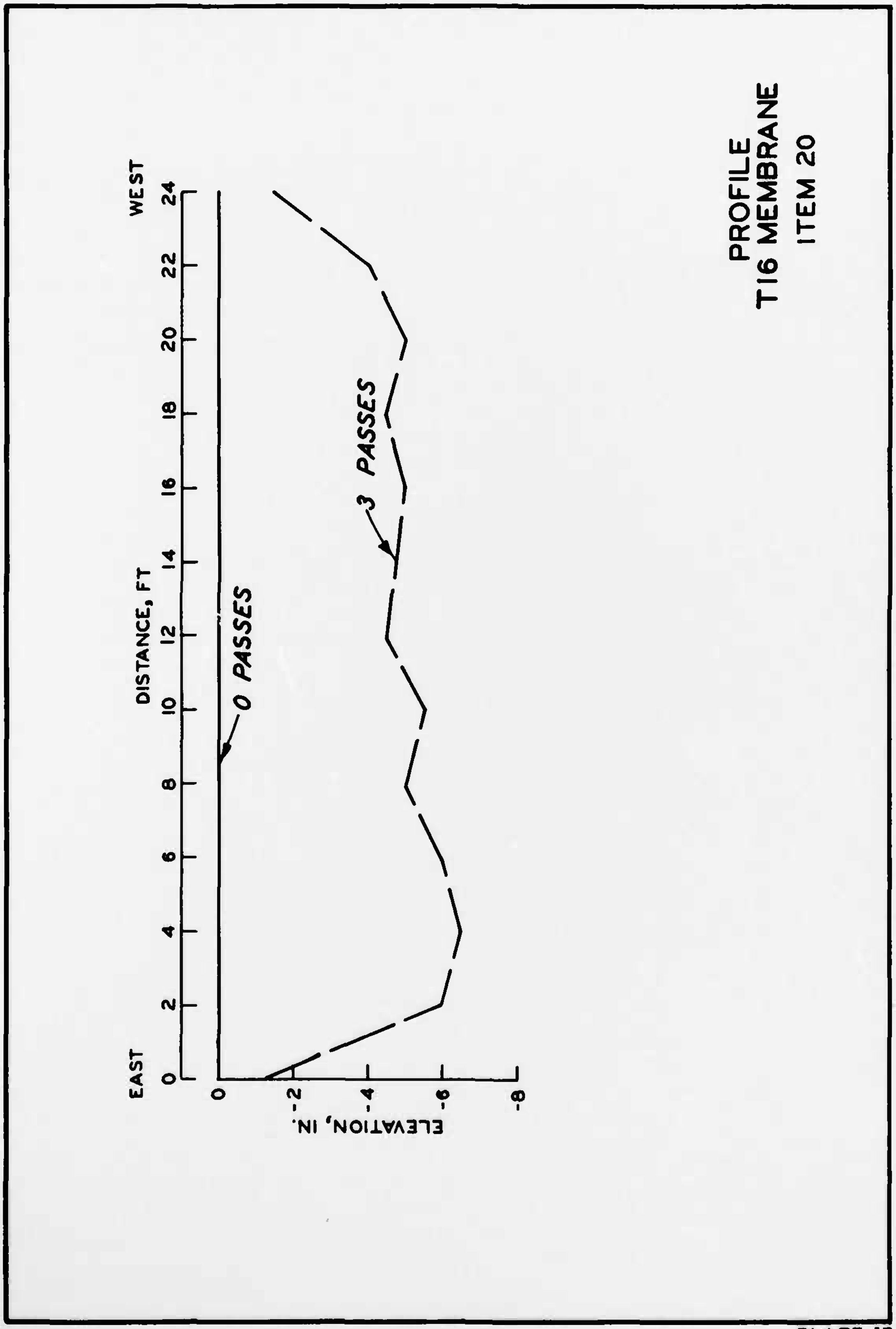


PROFILE
ECOLITE CORE, DOUBLE LAYERS
ITEMS 12 AND 13

PLATE 15



PROFILE
HEXCEL PAPER CORE,
SINGLE AND DOUBLE LAYERS
ITEMS 14 - 19



PROFILE
T16 MEMBRANE
ITEM 20

DATE
FILMED